ECONOMIC PLANTS

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ROBERT HEGNER, *Editor*

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ECONOMIC PLANTS

BY

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With 376 Illustrations

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PRINTED IN THE UNITED STATES OF AMERICA

DEDICATED TO THE MEMORY

OF

MY FATHER

GEORGE ELWIN STANFORD

PREFACE

For many academic generations, colleges and universities have offered instruction in botany and the biology of plants. Teachers of botany have dealt in much detail with the life and activities of plants and with their classification. Only very recently has there been any general effort to organize upon a college-grade basis the study of the utilities of plants to man. Inspection of present college and university curricula shows that, while instruction in economic botany is less commonly offered than courses, for instance, in plant physiology or plant pathology, the subject is much less neglected than it was a decade ago. Acquaintance and correspondence with a considerable number of botanists indicates that teachers of plant science are coming to realize that the utilities of plants, as well as their life and activities, have their proper claim upon a place in the educational program. That this should be so is logical enough. It would be indeed remarkable if the painful lessons of the last few years had not emphasized the necessity of scientific study of the nature, production, and distribution of the "useful" things of everyday life.

The present volume has grown from many years of interest and experience in various branches of economic plant science. It is designed to formulate a brief survey of several of the more important groups of plants and plant products utilized by the human race. While it is hoped that it may be useful to the professionally inclined student of plant science, it is planned primarily for that much larger group of students who wish to extend their knowledge of the kingdom of living things about them, the living green things upon which, in the last analysis, all human life depends. Among the author's own students, the most enthusiastic have been groups of teachers in high schools and in the upper grades of grammar schools, whose experience has brought them to realize the educational values of knowledge of common things. It has been their feeling that economic botany may occupy a very significant position in the teacher-training curriculum. *While the book is planned as a textbook, it is hoped that* it may also appeal to readers among the general *public* whose interest in plants and their utilities has no relation to credit-hours and graduation requirements.

While the subject-matter of this volume may be presented, if necessary, upon a lecture-and-demonstration basis, laboratory work is, of course, highly desirable. Illustrative exercises, to be planned in accordance with the preparation of students and with local opportunities, will readily suggest themselves to the teacher. Almost everywhere, moreover, may be found valuable opportunities for field observation of plant crops or forest products, as well as for inspection of industrial establishments where plant products are utilized.

Comprehension of the utilities of plants and plant products must be based upon some knowledge of the structure and composition of the materials concerned. The student of economic plants will profit by previous courses in the elements of biology or botany and by whatever knowledge he may have of chemistry. It is hoped, however, that this presentation of the economics of plants may be of use to many whose previous preparation in plant science has been brief or lacking. As a preliminary to the study of economic plant groups, the first chapter is designed to serve as a very brief orientation in the plant world; while the second embodies discussion, also abbreviated, of the structure of green plants. Students having botanical preparation may be assigned these chapters in brief review, or they may, at the discretion of the instructor, be omitted.

In the organization of material concerning such a wide variety of plant products, affecting human interests in such diverse ways, no attempt has been made to follow throughout a hard-and-fast or stereotyped method of presentation. For each group of subjects, the author has selected such material as seemed to him of special interest and significance. There is full realization that, to the specialist in particular subjects, the treatments may seem brief and circumscribed. Also, a number of important plant groups, such as the edible "vegetables" and the ornamental plants, are conspicuous by their absence. Limitations of this sort spring from the inadequacy of any one person to deal efficiently with the vast range of economic plant materials and from necessary considerations of space and time.

As an aid to both students and instructors, a rather detailed table of contents has been prepared. The author has found outlines to be of considerable value in presenting a sort of bird's-eye view of "what is coming" and of its organization. Students should find them useful in review.

Some use, but it is hoped not excessive use, has been made of statistics and maps. Such things, of course, have a way of appearing after a few years more obsolete than they really are. For those who desire to make more extensive use of statistical and allied material and to keep it up to date, there are such publications as the *Yearbook* of the United States Department of Agriculture, the occasional publications of that department's various Bureaus, the annual *Foreign Commerce and Navigation* statistics of the United States Department of Commerce, publications of the Bureau of the Census, and—less known to teachers than they should be—summaries and other publications and reports of the United States Tariff Commission.

Facts for the discussion of such a wide variety of subjects have necessarily been drawn from a vast number of sources—so many that suitable acknowledgments and citations would fill a large part of the volume. Without availing oneself of the aid, both published and that accorded most courteously in correspondence, of the United States Department of Agriculture, and particularly of its Bureau of Plant Industry, Forest Service, and Forest Products Laboratory, it would scarcely be possible to construct any worth-while work on economic plants. Researches and publications of many State experiment stations have been invaluable. Special thanks are due to the government services and to colleges and experiment stations, which have permitted the use of numerous photographs and illustrations, all made available through the hearty coöperation of numerous officials. Cordial acknowledgment is made of the courtesies of authors and publishers who have permitted the use of excerpts and illustrations from copyrighted works, all of which are duly credited where they appear.

Original drawings and diagrams have been done under the author's direction by Miss Elizabeth Coffman, Mrs. Helen McCarthy, and the Rev. E. L. Spuller, to all of whom it is a pleasure to make this acknowledgment of whole-hearted coöperation.

Thanks also are due to Professor R. H. Wetmore, of the Department of Botany of Harvard University, for editorial courtesies, criticism, and untiring interest.

Mrs. Alice L. Stanford and Miss Nancy Toms have rendered valuable assistance in proof-reading.

Any list of acknowledgments would be sadly incomplete without special mention of the author's students here at the College of the Pacific. They have been for several years subjects of his vagaries in educational experimentation, and for them this work has been brought to its present stage of development. Without their generous interest and enthusiasm this book would scarcely have appeared. If the published volume should meet a comparable response elsewhere, the labors of its construction will be amply compensated.

ERNEST ELWOOD STANFORD.

College of the Pacific,
Stockton, California,
March, 1934.

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ECONOMIC PLANTS

CHAPTER I

THE PLANT KINGDOM

The Cellular Structure of Plants

Plants are formed of one or more structural and physiological units, termed CELLS. The least complex of plants, the bacteria, consist of single cells. Nearly all other plants, however, are multicellular; and there is usually division of labor among the various cell-forms which make up the entire living structure. Cells are generally microscopic in size; a cubic inch of wood may contain millions of them, of several different forms, each form having its own relation to the life of the organism.

Essentially, a living cell (Fig. 1) consists of a body of living substance, PROTOPLASM. The protoplasm of a single cell is termed a PROTOPLAST; within it can usually be made out a specialized body, the NUCLEUS, which seems to be especially concerned with the metabolic changes which go on within the cell. Other protoplasmic bodies exist in some protoplasts, such as the plastids, which commonly have to do with food manufacture. Surrounding the protoplast, in nearly all plant cells, is a CELL WALL, which is commonly of cellulose or some related substance.

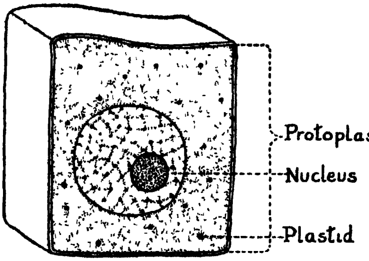

FIG. 1. — A Young Cell from a Rapidly Growing Root Tip. (E. L. Spuller.)

The activities, characteristics, and utilities of plants and plant parts result from the activities of protoplasts and from their ability to form various substances—such as the material of the cell wall and foodstuffs, the latter including carbohydrates, fats, and proteins. Before discussing further the nature and activities of individual cells, however, it will be well to form some idea of the various groups of plants whose cellular structures and organizations provide not only for their own existences but make our tenancy of the earth possible.

1. PLANTS OF THE PRESENT DAY

More than 225,000 species, or recognizable kinds, of plants now exist. Vast numbers of vegetable organisms which lived in the past have vanished; some, doubtless, leaving neither trace nor descendant. Could they be traced with entire accuracy, the genealogical lines of present-day plants would lead both to fossil and to wholly vanished ancestors. Plants of the present and those of the past whose remains are sufficiently distinctive for classification may be divided into various groupings. So far as our knowledge permits, the lines which divide these should be drawn according to natural affinities and relationships by descent.

At the present time, views concerning the relationships of certain plant groups are in a state of considerable flux. In the present work no discussion of these matters can be attempted. Under a system admittedly faulty, but which has the virtue of simplicity and the sanction of long usage, four major divisions, or subkingdoms, of the plant world are commonly recognized. These are the THALLOPHYTA or thallophytes, the BRYOPHTA or bryophytes, the PTERIDOPHYTA or pteridophytes, and the SPERMATOPHYTA or spermatophytes. The discussion which follows will outline the characters of each group briefly and will call attention, incidentally, to certain phenomena and principles which are common to the plant world or to the study of it.

Thallophytes

This group includes the most primitive of plants and some complex ones, listing a total of about 80,000 species. The category is made up of a rather miscellaneous assemblage of organisms whose principal bond of union is the evident fact that they do not belong in the other divisions named. While some of the larger thallophytes—such as the kelps (Fig. 2)—exhibit considerable specialization of structure, they lack the stem, leaf, and root differentiation of ferns and seed-plants. Most of them are of aquatic habit; those which do not live actually in water occur usually in very moist situations.

The relatively simple plant body of the thallophyte is called a THALLUS. Thalli vary in size from a thousandth of a millimeter or less in bacteria to a hundred meters or more in some of the

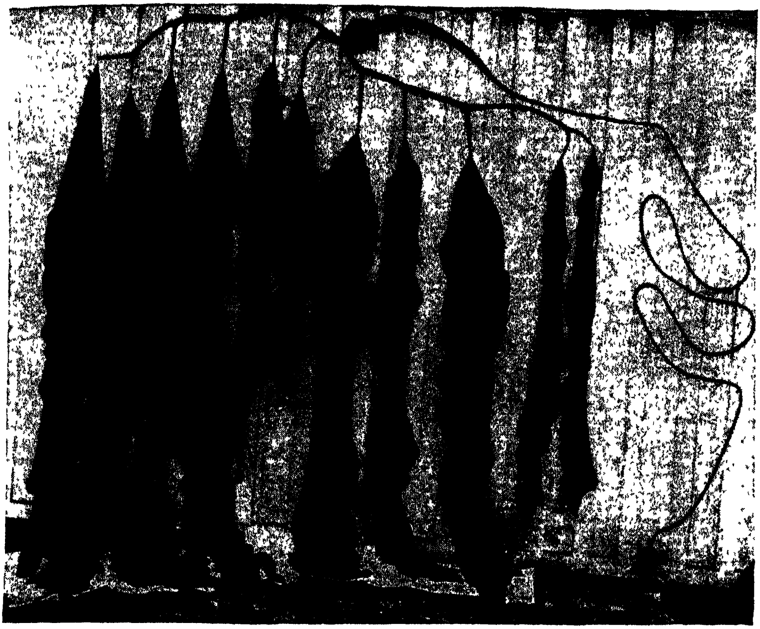

FIG. 2. — A Large Kelp (*Pelagophycus*) from the Californian Coast. (Photograph by W. A. Setchell. Reprinted by permission from *Textbook of General Botany*, by Holman and Robbins, published by John Wiley & Sons, Inc.)

giant seaweeds. Small forms may be spherical, ovoid, or ellipsoidal; large ones are likely to be threadlike (filamentous) or frondlike.

REPRODUCTION

The least complex of thallophytes, the bacteria (Fig. 3*A*), reproduce by simple division and, it has recently been discovered, by other means too complex to be discussed here. In division, one cell forms two, each a duplicate of the first. Bacterial cells may remain attached, but each cell appears to function independently. Each is self-sufficient, a living organism; there is no division of labor.

In multicellular thallophytes, certain cells generally assume the nutritive burdens of the organism, while others become specialized for the reproduction of the species. The simplest kind of reproductive cell is the SPORE, which is merely a slightly modified cell —often spherical, ovoid, or ellipsoidal in form (Fig. 4)—which by cell division gives rise to an organism like the one which bore it. Some spores are motile, swimming about in water by means of tiny whiplike appendages, the cilia. Spore reproduction is

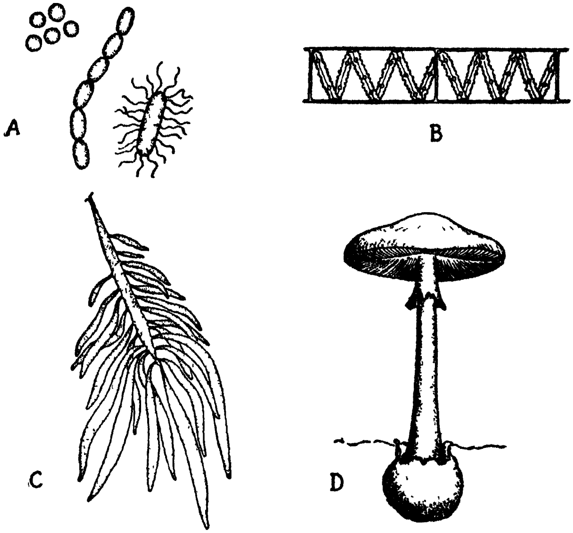

FIG. 3. — Various Thallophytes *A*, three forms of Bacteria; *B*, two cells of *Spirogyra*, a filamentous Green Alga; *C*, a frond of a Red Alga; *D*, fruiting body of a Mushroom. *A* and *B* are highly magnified. (E. L. Spuller.)

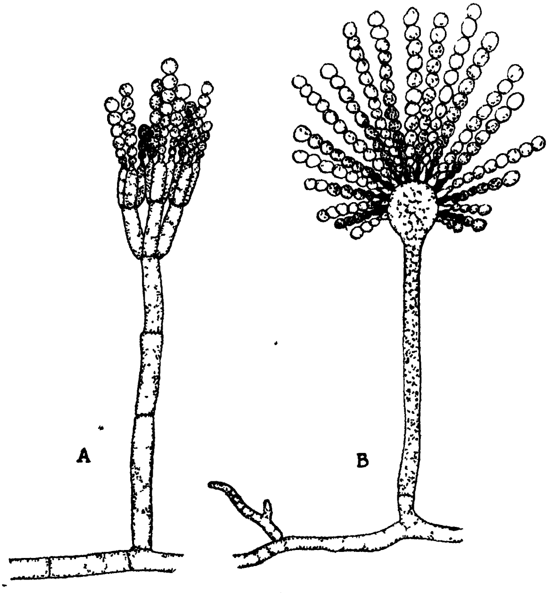

FIG. 4. — Spores of Two Common Fungi: *A*, a Blue Mold (***Penicillium***); *B*, a Black Mold (***Aspergillus***). Spores of both are borne in chains upon specialized branches of the filamentous plant body. The color of the spore-masses gives the "common names" to the molds. (Redrawn from Kny.)

ASEXUAL reproduction; only one plant is concerned in the formation of a spore, and spores, as such, do not unite.

In most thallophytes, however, and in all plants higher than this group, SEXUAL reproduction occurs. In its simplest form, as seen in certain algæ (Fig. 5), motile cells—sometimes scarcely

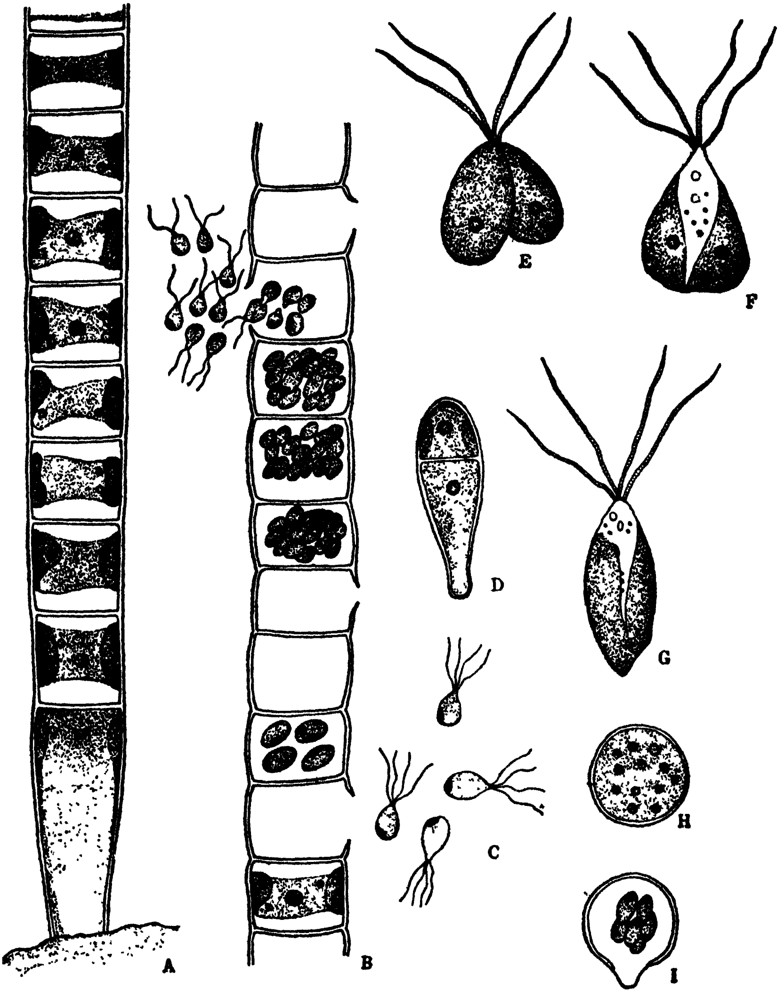

FIG. 5. — Sexual Reproduction in a Filamentous Green Alga (*Ulothrix*): *A*, a vegetative filament; *B*, a portion of a filament which is forming gametes (above) and motile spores or zoospores (below); *C*, escaped zoospores; *D*, a germinating zoospore; *E* and *G*, stages in the conjugation of gametes; *H*, zygote; *I*, zygote germinating to form zoospores which reproduce the vegetative filaments. (*E*–*H* after Oltmanns. Reproduced by permission, from *Textbook of General Botany*, by Holman and Robbins, published by John Wiley & Sons, Inc.)

distinguishable from spores—unite in pairs, forming a single cell which (in multicellular forms) proceeds to divide and directly or indirectly to regenerate the vegetative form of its kind. Uniting cells are called GAMETES, and the product of their union, a ZYGOTE. Union of like gametes is termed CONJUGATION. Most commonly, however, gametes differ from spores and from each other. In most plants which reproduce sexually there may be distinguished a female gamete, the EGG, and a male gamete, the SPERM (Fig. 6). Union of egg and sperm is called FERTILIZATION. In the three lower plant divisions, sperms are, with some exceptions, actively motile, swimming in water until they come in contact with eggs. The latter are almost invariably non-motile and are likely to be retained in the parent body until fertilization

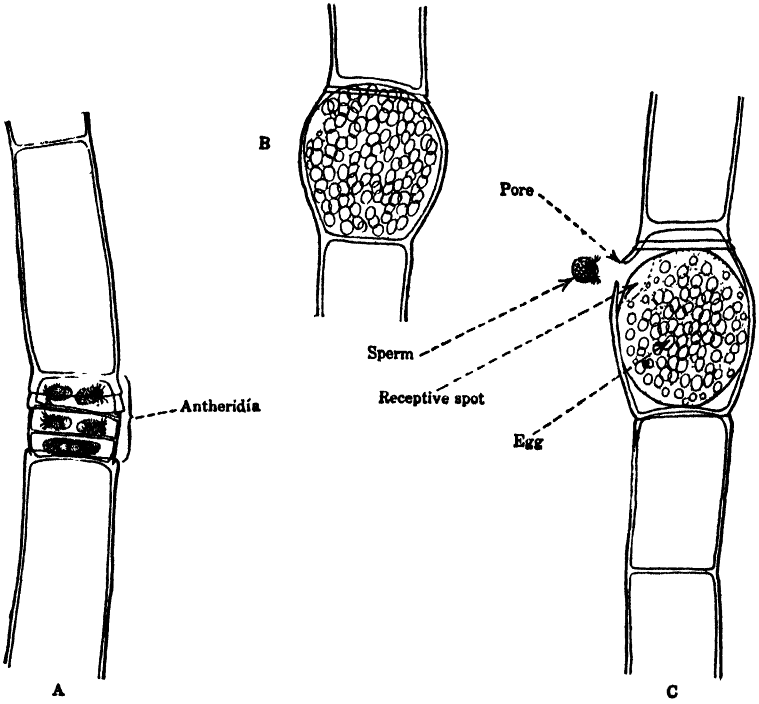

FIG. 6. — Sexual Reproduction in a Filamentous Green Alga (*Œdogonium*): *A*, portion of a male filament showing specialized cells, antheridia, in which sperms are borne; *B*, portion of a female filament showing a specialized cell, the oogonium, in which a single large egg is borne; *C*, sperm approaching egg (somewhat diagrammatic). (Reprinted by permission, from *Textbook of General Botany*, by Holman and Robbins, published by John Wiley & Sons, Inc.)

takes place—and even afterward. In seed-plants, most of which have lost sperm motility, other means are adopted to insure union of gametes.

Thallophytes and all other plants, to some degree, may reproduce by fragmentation. A severed part regenerates any lost portions which may be vital and proceeds to function as a new organism. Among seed-plants, this capacity is utilized in the familiar processes of budding and grafting, by means of which plants which do not "come true" from seed may be propagated.

Thallophytes are placed in two principal form-groups, the ALGÆ and FUNGI.

The Algæ.—Algæ include the red and brown fronded seaweeds which fringe the oceans; there are also many green algæ, including numerous filamentous forms (Figs. 5 and 6) whose tangled thalli abound in stagnant fresh waters or cover rocks in running streams. A few algæ have left the normal aquatic habitat of the group; they form green masses on soil or tree-trunks, or lose themselves, to the unaided vision, in the upper layers of the soil.

Although in many forms its color is masked by red, brown, or bluish coloring matters, all algæ possess CHLOROPHYLL, the green pigment which lends such characteristic hue to the "plants" of everyday observation. By means of chlorophyll, green plants of all sorts capture the energy of the sunlight. This they utilize in the fundamental constructive process of organic nature—PHOTOSYNTHESIS—"building by means of light." In photosynthesis, carbon dioxide and water are combined into CARBOHYDRATES—food substances in which the solar energy is stored as chemical energy for future use. From carbohydrates, other foodstuffs are formed. No one knows how many millions of years ago the first algæ thus made food. Such of their descendants as are still algæ continue the process in the water and form in seas and rivers the first link in the carbon chain or cycle upon which marine animal life directly or indirectly depends. During the slow lapse of ages, we believe, descendants of these primordial algæ have moved forward, usually progressing—though sometimes receding—in many and diverse directions. They have become extinct in some lines of progress and have continued onward in others, till to-day the earth is decked with the myriad forms of the mosses, ferns, and seed plants—algal descendants all, though showing little apparent evidence of their lowly origin. Algal descendants which are still green furnish food not only for themselves but, directly or indirectly, for the entire animal kingdom, including man. Save for a few microscopic forms which live in the water, and whose nature and existence point to a probable common origin of both plant and animal life, no animal can carry on photosynthesis or any other comparable form of food manufacture from simple things.

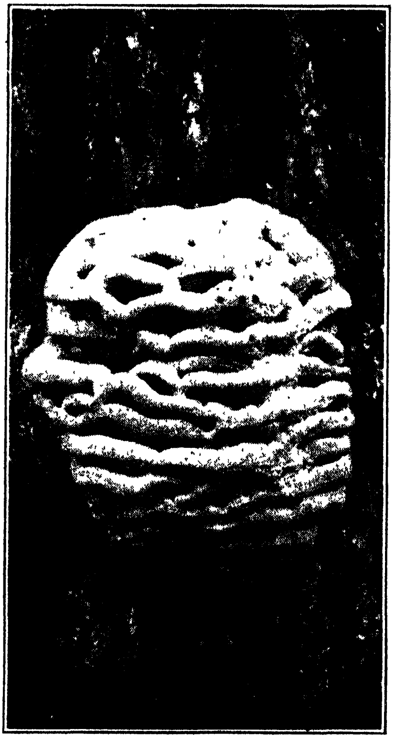

FIG. 7. — A Bracket Fungus (*Polyporus sulphureus*) on Elm. (Photo from Massachusetts Agricultural Experiment Station.)

The Fungi.—The fungi are thallophytes which lack chlorophyll. They vary in form from microscopic — perhaps from ultramicroscopic — bacteria (Fig. 3*A*) to the large mushrooms of the soil (Fig. 3*D*) and the bracket fungi (Fig. 7) which attack injured trees and destroy dead wood in the forest.

With the exception of certain groups among bacteria, the fungi rely for their organized nutriment on other organisms, living or dead, and thus depend, directly or indirectly, upon green plants. The fungi—with possible exceptions among the bacteria, which may represent the primordial form of life more closely than do anything else alive to-day—seem to be degenerate descendants of algæ. Degeneracy and loss of independence occur occasionally among higher plants, but the fungi form the only large group of plant dependants. The majority of fungus forms live upon dead organic matter; plant organisms of this habit are called SAPROPHYTES. Those which attack living things are termed PARASITES—a term by no means restricted to the plant kingdom.

Bacteria are not large, nor conspicuous, nor of remarkably numerous kinds. Often their individual numbers are beyond human comprehension. A single spoonful of garden soil may contain millions of bacteria. Inconspicuous as they are, the fungi and bacteria are indispensable in the pattern of nature. Without them, bodies of plants and animals would never decompose, would never liberate their locked foodstuffs in the soil for the benefit of other organisms. In the decay of animals, whose substance is chiefly protein, and in the decomposition of plant protein, bacteria are the chief agencies. Agricultural fertility in the soil, in fact, depends absolutely on the activities of several groups of bacteria. Not all of these are agents of decomposition; some are almost alone among organisms in their ability to capture and pass on to other forms of life the free nitrogen of the air, upon which, as much as upon the more active oxygen, all living things depend. Some bacteria, of course, are parasitic, pathogenic. They cut short the lives of other organisms—of valuable plants, of animals of all sorts, of great men, and of lesser ones. These pathogens, however, are relatively few among a category of living things whose activities, in general, the self-centered human race may well consider beneficial.

Higher fungi are perhaps less obvious in the general scheme of things, but their relation to everyday life is far from negligible. They play the major rôles in the decompositions of cellulose and woody materials of plant bodies. Fungi of parasitic proclivities destroy crop plants; they have in the past produced famines and forced major migrations upon human kind. Activities of yeasts—degenerate fungi—in sugar solutions provide us with social and economic problems of first-rank importance.

While volumes might be written upon the economic significances of the thallophyte group, a detailed discussion of these organisms would lead us far from the consideration of the larger, more conspicuous, and more generally interesting plant groups which are the subject of the present volume.

Bryophytes

This inconspicuous plant category of about 16,000 species includes the true MOSSES (Fig. 8) and the LIVERWORTS (Fig. 9). Most of the latter are thalloid forms, found in damp situations. Plant bodies of mosses and some liverworts show primitive differentiation into stem and leaf, though the latter organ probably is not homologous with the leaf of seed-plants. Bryophytes possess simple fibrous organs of attachment, called rhizoids. In this division, as well as in pteridophytes and spermatophytes, appears ALTERNATION OF GENERATIONS, a phenomenon which is occasional but not general among thallophytes. The conspicuous, leafy plant of

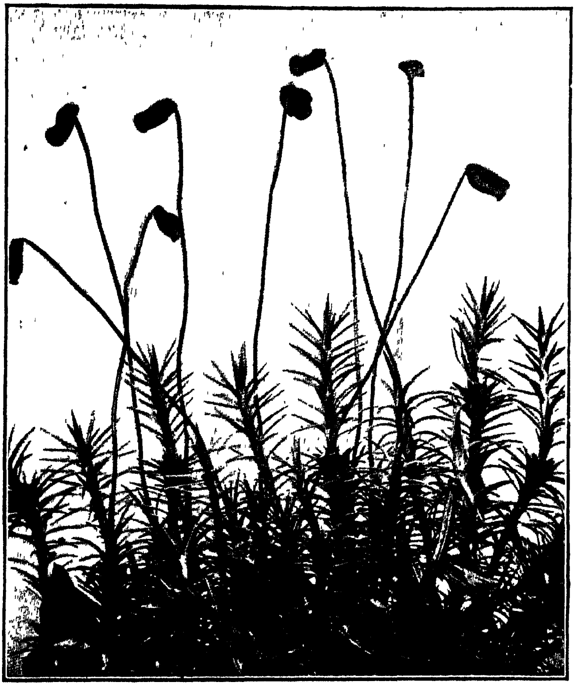

FIG. 8. — A Common Moss, a Hair-Cap (*Polytrichum juniperinum*). (From *Mosses with a Hand-Lens*, by A. J. Grout, third ed., 1924.)

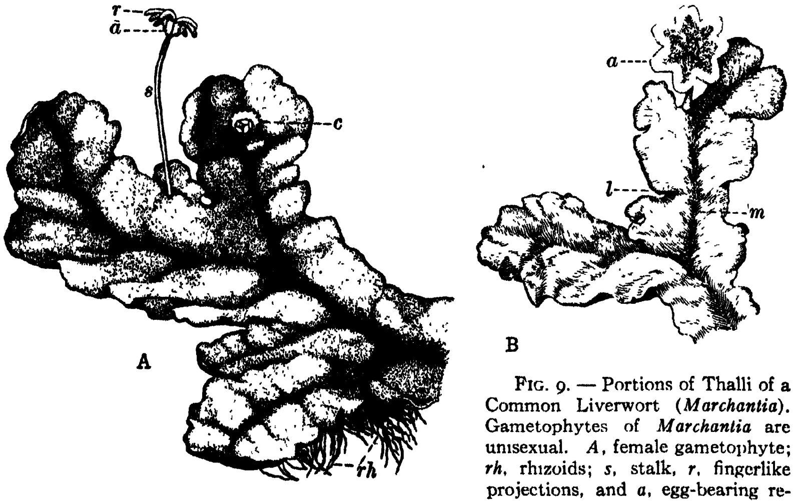

FIG. 9. — Portions of Thalli of a Common Liverwort (*Marchantia*). Gametophytes of *Marchantia* are unisexual. *A*, female gametophyte; *rh*, rhizoids; *s*, stalk, *r*, fingerlike projections, and *a*, egg-bearing region of specialized branch in which eggs are borne; *c*, cupule, in which structures directly reproducing the gametophyte are borne. *B*, male gametophyte; *l*, leaflike expansion; and *m*, midrib, of thallus; *a*, specialized branch in which sperms are borne. (From

the moss is a gamete-bearing plant, or GAMETOPHYTE (Fig. 10). Gametes are borne in the tuft of leaves at the extremity of moss plants. Union of egg and sperm takes place in a flask-like organ which bears the egg; there the zygote develops as a stalklike structure with an elongated capsule at its apex. In the capsule are borne asexual spores; these, scattered in the wind, germinate in favorable situations and produce gametophytes. The spore-bearing plant, which depends for nutrition upon the gametophyte and which looks like a part of it, is termed the SPOROPHYTE. Gametophytes may multiply by branching and breakage, or even in some liverworts by specialized bodies which reproduce them, but the usual sequence, or alternation of generations, is gametophyte, sporophyte, gametophyte, sporophyte—and so on *ad infinitum.*

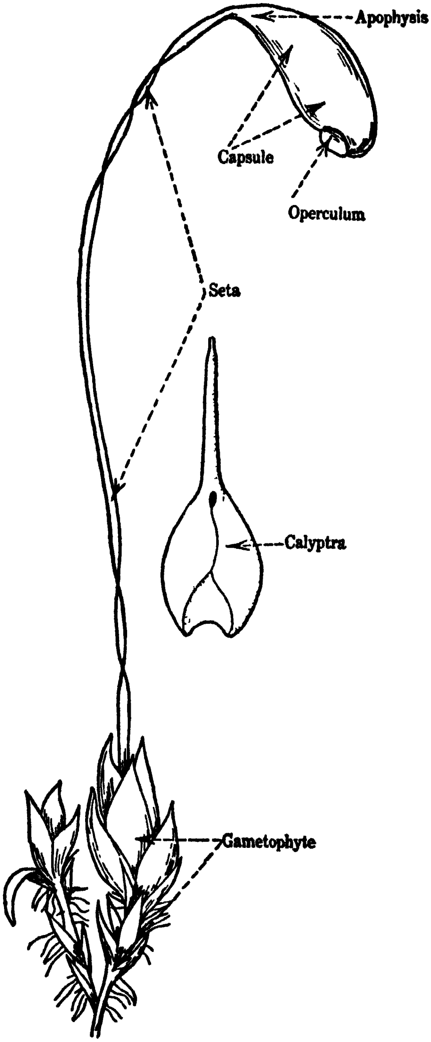

FIG. 10. — Portion of a Gametophyte and Attached Sporophyte of a Moss (*Funaria hygrometrica*). The seta is a stalklike portion of the sporophyte. The calyptra is a membrane, derived from the gametophyte, which is pushed upward by the growth of the sporophyte, covering the capsule of the latter. (Reprinted by permission, from *Textbook of General Botany*, by Holman and Robbins, published by John Wiley & Sons, Inc.)

The bryophytes are characteristically small plants, found usually in damp locations. Undoubtedly they are of some significance in the breakdown of rock into soil; they may be of minor value in preventing soil-waste by erosion. The remains of some form peat, occasionally used as a fuel. No group of organisms which carries on photosynthesis is wholly negligible. As compared with any of the other divisions, however, bryophytes are of small importance to the world of men.

Pteridophytes

This group is the smallest of the four plant divisions, including about 6,000 species. Its principal subdivisions are the FERNS (Fig. 11), the HORSETAILS, and the CLUB-MOSSES (Fig. 12).

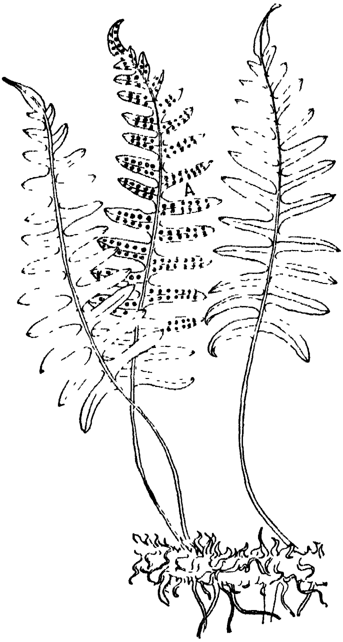

Fig. 11. — The Sporophyte of a Fern (***Polystichum munitum***): *A*, sporophyll, seen from lower (ventral) surface; the dark dots are sori, in which spores are borne in saclike structures (sporangia). (E. Coffman.)

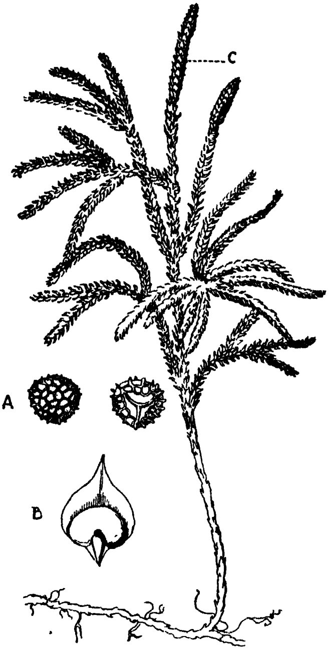

Fig. 12. — The Sporophyte of a Common Club Moss (***Lycopodium obscurum***). *A*, spores; *B*, sporophyll, which bears spores in a sac (sporangium) near its base; *C*, strobilus, made up of sporophylls clustered at the apex of the stem. (E. Coffman.)

These are all green plants; the ferns are well differentiated into roots, stems, and leaves, which resemble in organization those of seed-plants. Horsetails have vestigial leaves and carry on photosynthesis only in their stems. Leaves of club-mosses resemble those of mosses, but the two classes are clearly separated by their reproductive characters and by the generally greater complexities of club-moss structure. Pteridophytes possess specialized supportive and conductive tissue-associations, fibro-vascular bundles, which are lacking in the lower groups. As to reproductive characters, the large and conspicuous fern, horsetail, or club-moss is the sporophyte. In most ferns, spores are borne in specialized structures, sporangia, on the back of leaves, which are therefore termed sporophylls. Germination of fern spores gives rise to very small and delicate gametophytes (Figs. 13 and 14). These generally develop only in very moist situations, and the "man in the street" rarely sees them, or does not notice them if he does see them. Union of sperm and egg takes place in egg-bearing organs, as in the bryophyte, but here the similarity ends. The developing zygote soon establishes its own ground-contact and produces root,

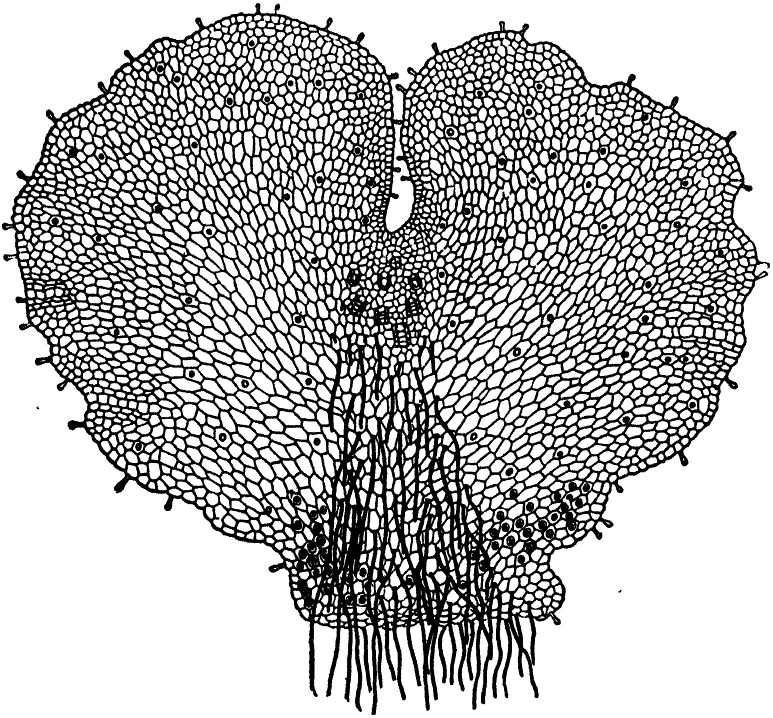

FIG. 13. — Gametophyte of a Fern (*Aspidium*), Seen from Below. Among the hair-like rhizoids are antheridia, which bear sperms; above them are archegonia, which bear eggs. (From Coulter, Barnes, and Cowles' *A Textbook of Botany*, Volume I. Copyright, 1910, by American Book Company, and used with their permission.)

stem, and leaves. As a matured sporophyte, it may live for hundreds of years; indefinitely perhaps, unless accident overtakes it.

At one time the pteridophytes dominated the vegetation of the globe; the coal-measures are the carbonized remains of giant pteridophytes and primitive seed-plants, perhaps their descendants. Ferns and fern-allies of the present day, however, rarely attain tree-size; economically speaking, they are plants with a past rather than plants of the present or with probable future. Some of them are valued for their beauty; others are despised as weeds. Some cause stock-poisoning.

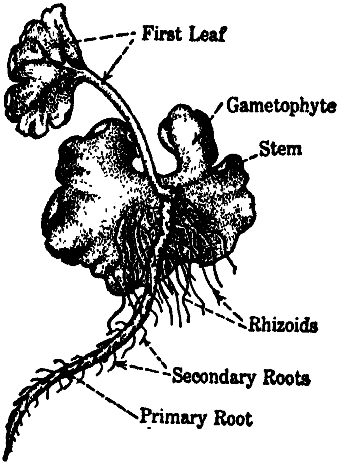

FIG. 14. — Early Stages of Development of a Fern Sporophyte. (Reprinted by permission, from *Textbook of General Botany*, by Holman and Robbins, published by John Wiley & Sons, Inc.)

Spermatophytes

These are the seed-plants, a large and varied group, possessing the greatest differentiation of structure and the most efficient adaptations for life upon land. They are variously estimated at between 120,000 and 150,000 species. They are the PLANTS of our everyday speech. In them the gametophyte stage is reduced to a vestige. Eggs are produced within microscopic female gametophytes which are in turn produced within the structures of flower or ovulate cone. They are fertilized by sperm nuclei from the pollen grain which, developed, represents the male gametophyte. The zygote thus formed becomes an embryo, which passes through a stage of arrested development in a structure not found in other divisions—the SEED.

Seed-plants make up our forests; they clothe our hills and valleys; they beautify our parks and gardens; they shade our dwellings and streets. They afford our entire supplies of wood, timber, and lumber. From them come paper and pulp. They furnish all our textile fibers save natural silk, wool, and the hair of a very few animals used for spinning and weaving, though even silk and wool are seed-plant material at second-hand. Seed-plants yield us cellulose, rubber, resins, tanning materials, and cork. Carbohydrates, fats, proteins, and nearly all the vitamines come from their green laboratories where carbon dioxide from the air joins water, minerals, and nitrogen from the soil. Spices and aromatics—pleasant and otherwise—and alcoholic and caffein-bearing beverages are seed-plant products, wholly or in part. Seed-plants compete with each other; they become weeds, adding to the vexations of the farmer. Some poison stock and man also, though the poisons of a few are turned by the physician to human benefit. While other plant groups have their own claims upon the student of plant economics, the present treatise attempts merely to present some of the manifold significances to the human race of seed-plants and their products.

It will be essential, therefore, to form some idea of the principal subdivisions of the seed-plant group. Also, as both the activities of the plant and the utilities of plants and plant products to man depend upon the physical and chemical composition of the plant body, both the cellular structure of plants and the nature of substances which they form must later receive some attention.

2. GROUPINGS AMONG THE SEED-PLANTS

Systematic Classification of Plants

Among thousands of seed-plant species is found almost infinite variation in vegetative characters, flower or cone-structure, and type of fruit and seed. Extensive study of plants of the present and of the remains of those of their forebears which still exist as fossils have yielded considerable knowledge of seed-plant affinities. The picture we can form of their relationships is, however, far from complete. While valuable knowledge of kinship can sometimes be gained by comparative studies of other plant parts, it is believed that the characters of organs concerned with reproduction offer the best criteria of relationship. Categories among seed-plants are therefore based largely on studies of flower or cone and fruit resemblances and differences.

Below the division, the groupings ordinarily employed, in descending order, are class, subclass, order, family, genus, species, and variety. All of these are convenience-categories—concepts formed by scientific minds for the better study, identification, and designation of plants and plant kinds. Similar groupings are made among thallophytes, bryophytes, and pteridophytes. Zoölogists have adopted corresponding methods in the classification of animals.

The groupings most commonly referred to in this volume will be FAMILIES, GENERA, and SPECIES. Briefly, it may be said that a species is a category of individuals which constantly show pronounced resemblances — virtual identities — in characteristics which students of the group in question have come to consider indicative of very close relationship. Genera are groups of species; families, groups of genera; orders, groups of families. Subclasses make up classes; classes form divisions. For some purposes, other categories—subgenera, subspecies, and the like —are made for special particularity. Subspecies and varieties are often of limited geographic range; the differences which separate them are likely to be fluctuating, inconstant, perhaps often the result of environmental influences. In some cases varieties probably represent species in the process of formation.

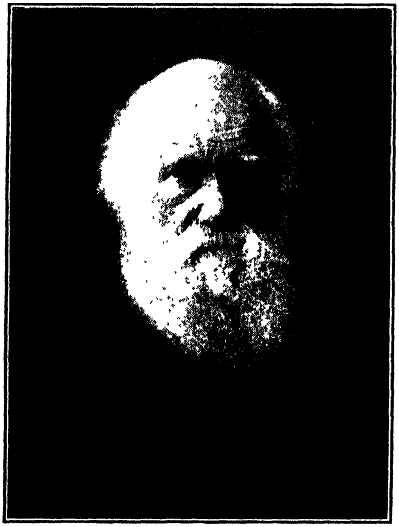

FIG. 15. — Charles Darwin (1809–1882). The brilliant and laborious exposition of the Theory of Evolution by this noted English scientist placed the doctrine in the forefront of scientific thought and established it as one of the cornerstones of modern biology. (From Joseph Mayer, *The Seven Seals of Science*, The Century Co., 1927, by permission of D. Appleton-Century Company.)

The Theory of Evolution

Presumably, the individuals which make up a species are descendants of a common ancestor in the relatively recent (but from the viewpoint of our own span of existence very remote) past. Species which make up a properly constituted genus should also be from a common, though more distant, ancestry. Thus the idea of descent may be continued into the past till the ancestral lines of all plants converge in a common primordial living organism. As to the forces and influences which have brought about this gradual descent and modification, this infinitely slow yet constant development of new forms from old, we have little scientific knowledge. As to the fact that such development has occurred—and that it is still going on to-day—we have so much evidence that the Theory of Evolution has become one of the cornerstones of biological science.

The Scientific Naming of Plants

Plants of everyday life bear "common names"—walnut, yellow pine, sycamore, and the like. Unfortunately for scientific use, however, such names are neither exact nor standardized. "Walnut" includes several closely related species. The "yellow pine" of the Pacific States is decidedly different from the "yellow pine" which borders the Gulf of Mexico. "Sycamore" has been applied to at least three different plants, of three separate orders, which have little in common save tree-stature and a superficial resemblance of leaf.

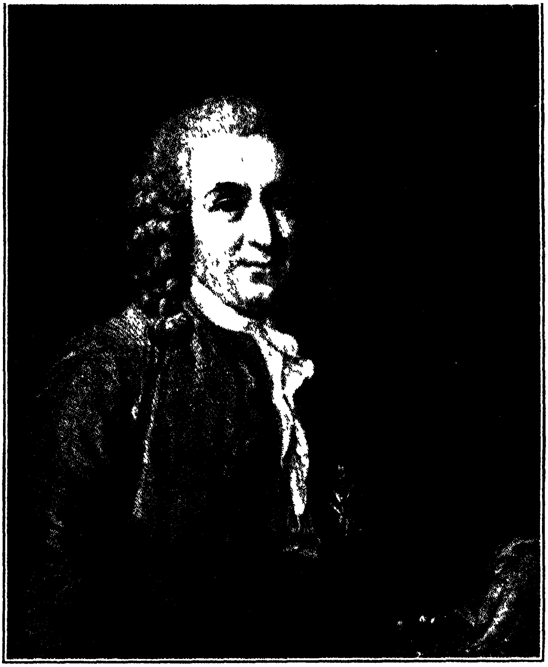

FIG. 16. — Carl von Linné (Carolus Linnaeus, 1707–1778). This great Swedish scientist systematized biological classification and simplified and clarified its nomenclature by introducing the *binomial system*, under which each plant or animal is designated by a genus-name plus a single species-name (From Joseph Mayer, *The Seven Seals of Science*, The Century Co., 1927, by permission of D. Appleton-Century Company.)

Therefore, for necessary accuracy in designation, scientists have been forced to devise a scientific system of naming the various categories of plants. This is so planned that duplications of naming and the use of two different terms for the same plant or plant-group do not occur—in theory, at least. Under this system, each species is designated by its genus name followed by its species name. The various walnuts become *Juglans regia* (the English or Persian Walnut), *Juglans nigra* (the Eastern Black Walnut), *Juglans cinerea* (the White Walnut or Butternut), etc. *Juglans,* with five other closely related genera (including in our flora *Carya,* the group of Hickories), make up the family Juglandaceæ, which happens to be the only existent family in the order Juglandales of the subclass Dicotyledoneæ, class Angiospermæ, division Spermatophyta.

For many purposes, of course, entire precision of naming is not essential or even suited to particular needs. While there are several species of Flax, one—*Linum usitatissimum*—is so much the "flax" of everyday commerce that the constant use of its scientific binomial would be pedantic. "Pine," while a group-name for seventy or more species, is definitive enough when separation from other conifer groups—spruce, cedar, hemlock, and the like—is the only immediate necessity. In this volume, both scientific and "common" names will be employed in accordance with the exigencies of particular discussions.

Classes of Spermatophytes

Seed-plants fall into two well-defined groups, the GYMNOSPERMS and the ANGIOSPERMS.

GYMNOSPERMS; THE CONIFERALES

Gymnosperms are much the smaller of the two classes, numbering at the present time only about 550 species. They are more primitive; from them, most probably, the angiosperms have arisen. Of the several gymnosperm orders, some have long been extinct, and others are now represented only by vestiges. A single order, the Coniferales, includes all the gymnosperms of much economic importance; the following brief discussion therefore applies to plants of that group.

Conifers are woody plants, mostly attaining tree-size. Their largest representatives, the sequoias, are probably the most gigantic plants which have ever lived. The characteristic habit of conifer growth is excurrent (*Fig. 17*) as contrasted with the usual deliquescent form of angiosperm trees (Fig. 22). The stem of the excurrent trunk shoots vertically upward without major divisions, dominating the small branches which often occur in whorls. A well-grown pine, fir, or young sequoia has thus a symmetrical conic aspect.

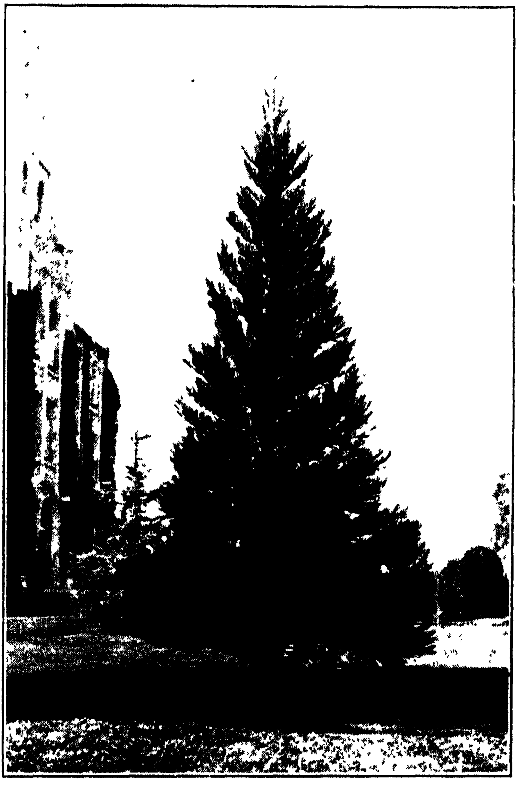

FIG. 17. — The Excurrent Habit of a Conifer: a Young Big Tree (*Sequoia gigantea*).

Stem-structure resembles that of the woody dicotyledon (Fig. 27).

The leaves of pines and many other common gymnosperms are needlelike; those of others, such as the arbor vitæ and incense cedars (Fig. 18) are scalelike, closely clothing the branchlets, which spread in fronds. Nearly all the conifers are evergreen. Their foliage members are densely compact in structure, water-

retentive, capable of carrying on photosynthesis at low temperatures and with little moisture supply.

The reproductive structures of the conifers are borne in STROBILI, more commonly called CONES, which are of two sorts, STAMINATE and OVULATE. In the pines and many other groups, staminate cones are borne in clusters at branch-ends (Fig. 19); their tiny balloonlike pollen grains are scattered in myriads and for vast distances by air currents. Some of them fall by chance into scale-crevices of developing ovulate cones, and here fertilization takes place. Ovules, in which eggs are produced, are borne in pairs on the upper surfaces of the scales of the ovulate strobilus. As a result of a rather complicated process of fertilization and development, these become seeds. At maturity, the leathery cone-scales (Fig. 20) of most pines and closely related conifers shrink away from one another, and the bared seeds fall out. Often these

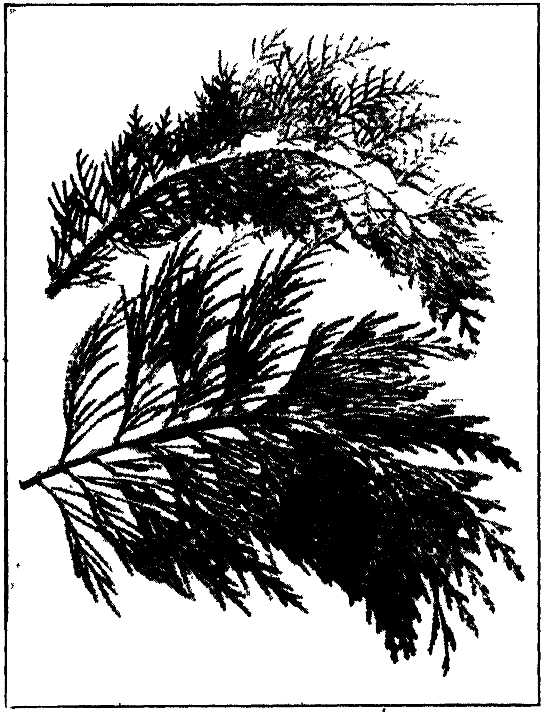

FIG. 18. — Scale-Leaved Conifers; above, Arbor Vitae (*Thuya*); below, Incense Cedar (*Libocedrus*).

possess bladelike appendages, formed from scale-tissue, which facilitate their dispersal.

On germination (Fig. 21), the conifer seed produces a miniature root, a stem, and from two to several seed-leaves or cotyledons, whose function of photosynthesis is presently assumed by the true leaves characteristic of the species.

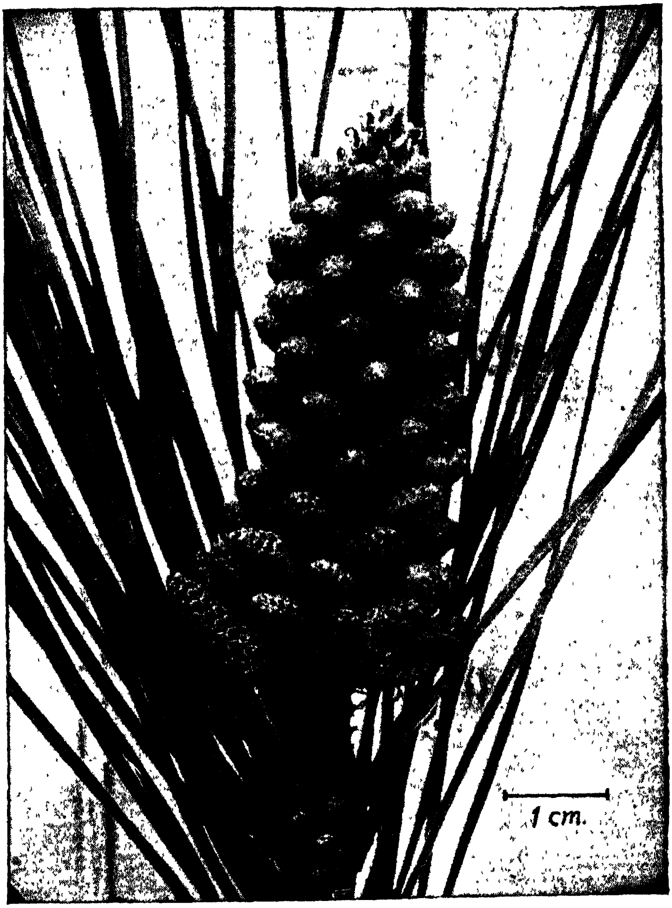

FIG. 19. — Staminate Cones of a Pine. The lower ones are shedding pollen; those above are still immature. (Reprinted by permission, from *Textbook of General Botany*, by Holman and Robbins, published by John Wiley & Sons, Inc.)

Conifers are of special abundance in the forests of the northern hemisphere. They are of chief significance in the lumber industries and as sources of wood-pulp, paper, and cellulose. They yield resins, turpentine, and a variety of minor products.

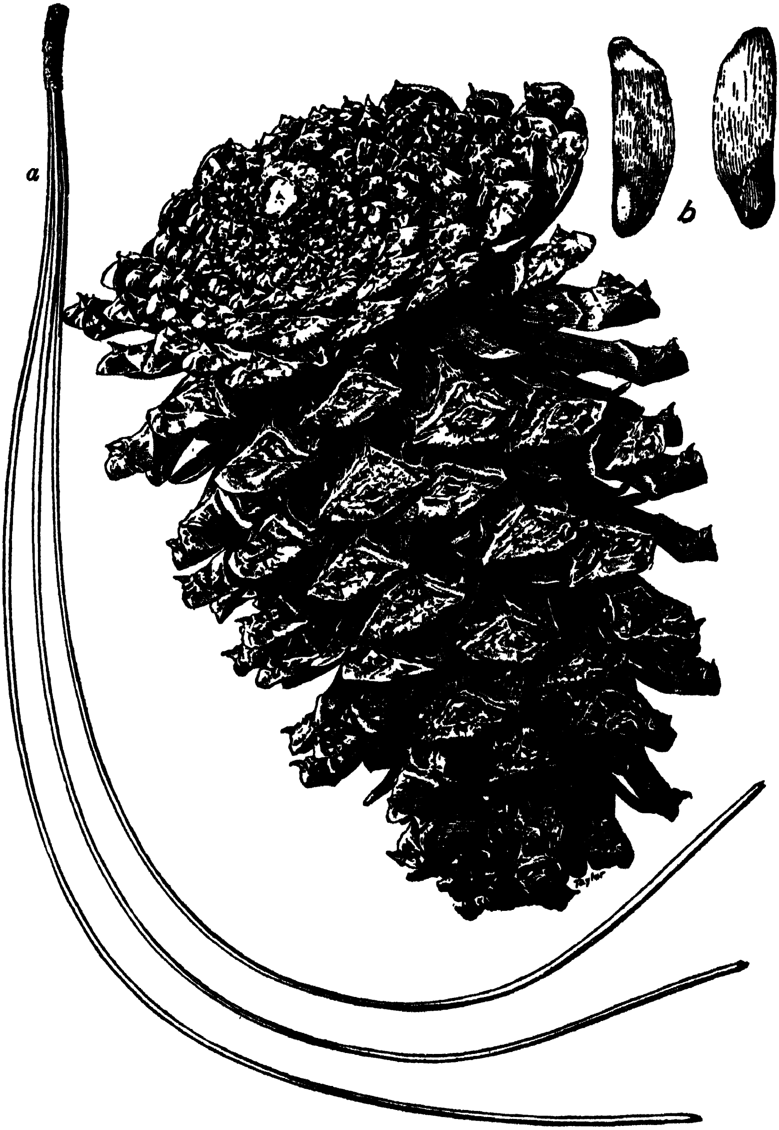

FIG. 20. — Leaf-Bundle, Cone, and Seeds of One of the Most Widespread American Pines, the Western Yellow Pine (*Pinus ponderosa*). (From Sudworth, *Forest Trees of the Pacific Slope*, United States Department of Agriculture.)

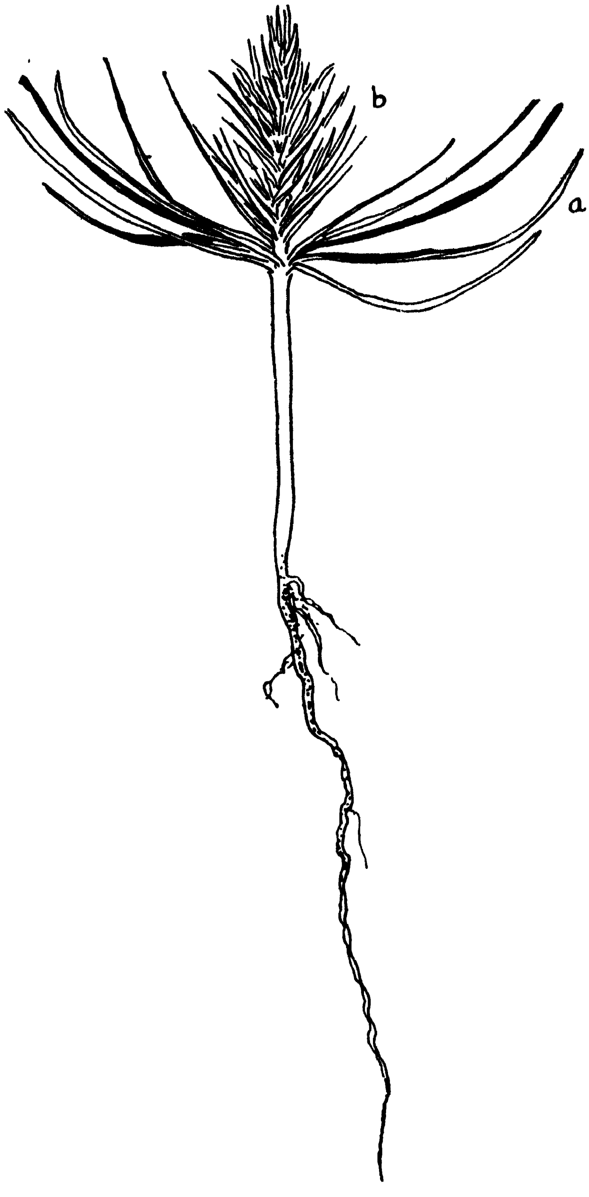

FIG. 21. — Seedling of a Pine (*Pinus*). This shows the numerous cotyledons (*a*) and the smaller and narrower foliage leaves or needles (*b*). (H. McCarthy.)

ANGIOSPERMS

The angiosperms are the flowering plants. Latest to develop among plant groups, they now dominate our terrestrial vegetation in numbers of kinds. Though outranked in numbers of individuals by microscopic thallophytes, their vastly larger size renders them dominant also in the visible clothing of the globe. While the gymnosperms are mainly woody and perennial, angiosperms afford herbaceous ANNUALS, BIENNIALS—plants requiring two seasons for fruition—and PERENNIALS, in abundance. Their woody forms are shrubs and trees of all sizes. Most angiosperm trees are naturally short-trunked with many spreading branches —DELIQUESCENT (Fig. 22)—a type of growth not conducive to lumber value. With the exception of a few degenerate forms, angiosperms have well-defined roots and stems, of structure more complex than those of conifers. Their leaves are usually broad, green, of "everyday" type, though sometimes so modified as to

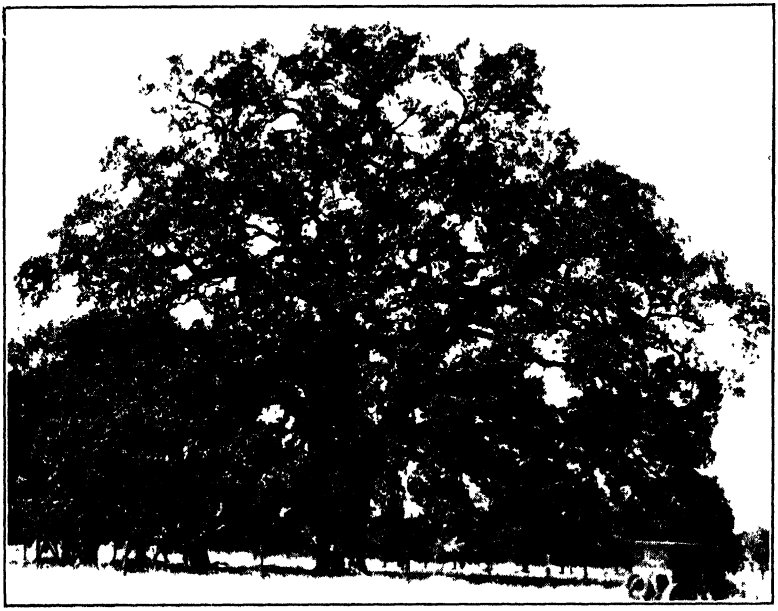

FIG. 22. — Deliquescent Form of a Dicotyledonous Tree: the California Valley Oak (*Quercus lobata*). This specimen, known as the Hooker Oak, in memory of the famous British botanist, Sir Joseph Hooker, is said to be the largest oak in existence. It is located at Chico, California. It has been computed that nearly 8,000 men could stand in its shade.

be all but unrecognizable as foliar organs. The most characteristic structure of the group is the FLOWER—a group of specially modified leaves, all concerned, directly or indirectly, with reproduction.

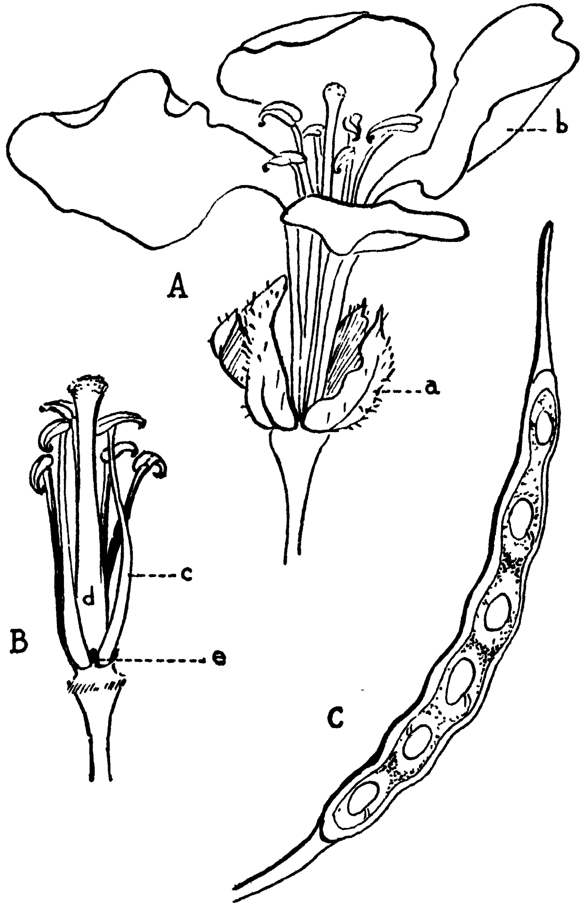

FIG. 23. — Flower and Fruit of an Angiosperm, a Mustard (*Brassica*). *A*, flower; *a*, sepals; *b*, petals; *B*, same with calyx and corolla removed; *c*, stamens; *d*, pistil; *e*, nectaries, in which are borne a sweet secretion attractive to insects; *C*, fruit in longitudinal section, with seeds shown within. (H. McCarthy.)

Flower and fruit of the angiosperm.—A typical and complete flower, such as that of a mustard (Fig. 23), possesses four sets of modified leaves, some not at all leaflike in appearance. The outer floral envelope, the CALYX, made up of SEPALS, is commonly green; it serves to protect the developing parts within the flower-bud from the dryness of the outside air. Within the calyx is a second envelope, the COROLLA, of several PETALS. Petals of the

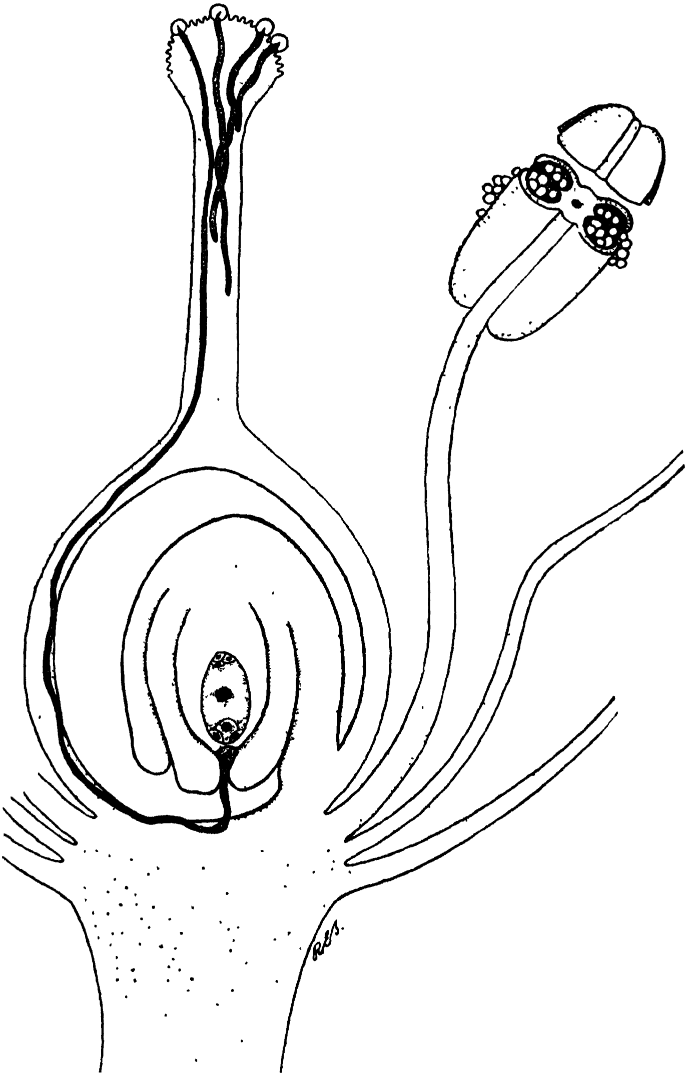

FIG. 24. — Fertilization in an Angiosperm. In the center is the pistil, shown in median longitudinal section. Several pollen grains have germinated upon the stigma; the tube of one of them has reached the single ovule and is about to discharge its sperm nuclei. At the right is an anther, cut in cross-section, showing pollen grains. (From Torrey, *General Botany for Colleges*, The Century Co., 1932, by permission of D Appleton-Century Company.)

more showy flowers contrast in color against the green of surrounding foliage; they thus attract insects, which serve themselves from nectar-supplies and pollen-abundance, involuntarily repaying the debt by carrying pollen grains on legs and bodies and losing some of them on the receptive stigmas of other flowers.

Within the floral envelopes are the essential organs of the flower, STAMENS and PISTILS. The first bear pollen; the second, ovules. Pollen occurs in boxlike compartments, the anthers, whose stalks are called filaments. A complete pistil is of three parts: a basal ovary, within which are one or more ovules; a terminal stigma, receptive to pollen of the same species; and a style which connects the two.

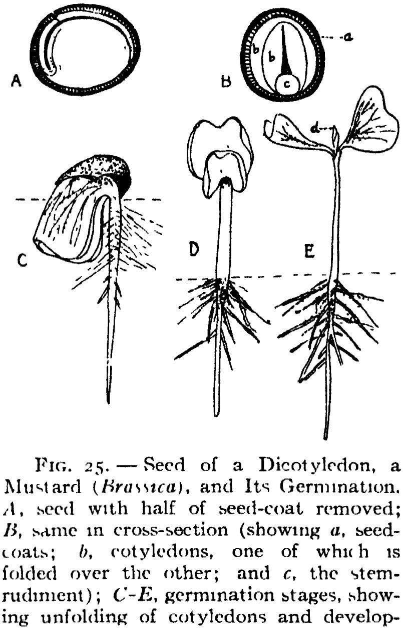

FIG. 25. — Seed of a Dicotyledon, a Mustard (*Brassica*), and Its Germination. *A*, seed with half of seed-coat removed; *B*, same in cross-section (showing *a*, seed-coats; *b*, cotyledons, one of which is folded over the other; and *c*, the stem-rudiment); *C–E*, germination stages, showing unfolding of cotyledons and development of stem, roots, and *d*, the plumule or first true foliage-bud. (H. McCarthy)

In the process of fertilization (Fig. 24), pollen grains germinate; the resulting tubular structure is the male gametophyte. This grows down through stigma and style, enters the ovule, which contains the microscopic female gametophyte. From the pollen-tube, two sperm-nuclei are discharged. One unites with an egg nucleus; the other with a fusion nucleus formed from two so-called polar nuclei. This is DOUBLE FERTILIZATION; one zygote develops into the EMBRYO; the other forms the ENDOSPERM, a nutritive cell-mass sometimes absorbed by the embryo in the process of seed-development but in other cases developing into a supply of stored food considerably surpassing the embryo in bulk. Such endosperms are utilized in the germination process. Often, as in the cereal grains, they are valuable storehouses of food for men and animals.

A seed consists essentially of an embryo plant in a resting or dormant state, with or without endosperm, and enveloped in seed-coats, usually two in number. While the seed is developing, the ovary generally increases in size and often undergoes various modifications in structure. At maturity of the seed, the ripened ovary becomes the fruit—a term which, in scientific usage, is not quite synonymous with the "fruit" of the grocery store. In contrast to the open seed-bearing structure of the conifer, the angiosperm fruit is closed at maturity. If its wall, or pericarp, opens in a definite manner—as it often does—it is through rupture of tissues. Such regular rupture is called dehiscence.

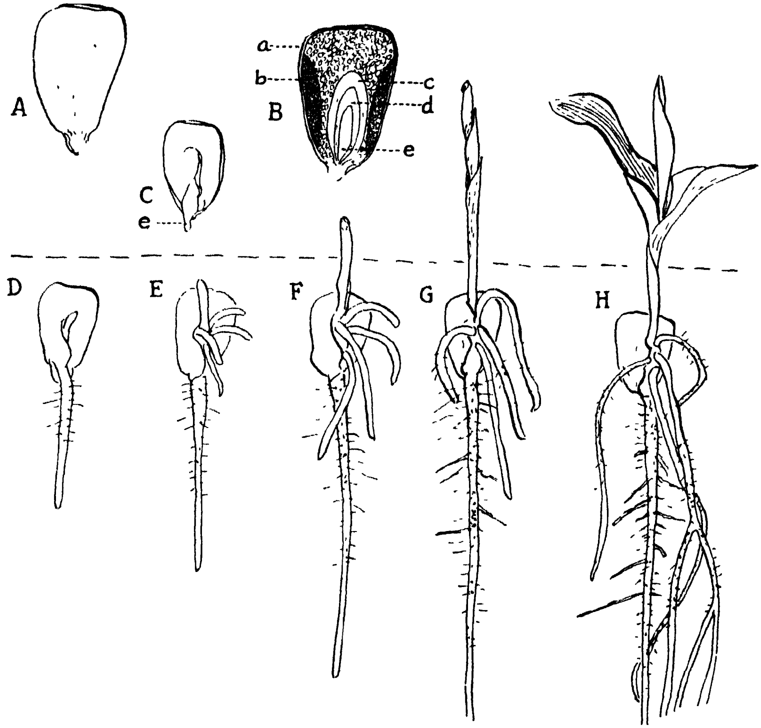

Fig. 26. — Seed of a Monocotyledon, Indian Corn (*Zea Mays*), and Its Germination. *A*, the fruit, or grain, seen from without; *B*, same in section, showing *a*, a fruit wall (pericarp) and seed-coats so tightly grown together as to seem a single structure; *b*, the endosperm (of two portions — the lighter area is the *soft starch* and the darker the *hard* starch); *c*, the cotyledon, *d*, the plumule or scroll of first leaves; *e*, the root-rudiment or radicle — both plumule and radicle are enveloped by sheathing structures whose differentiation is not shown —; *C-H*, germination stages; the cotyledon remains within the seed digesting the endosperm and transmitting its nutriment to the developing seedling. Note that the plumule develops as a spiral of sheathing leaves encircling the stem, which at this stage is scarcely differentiated. (H. McCarthy.)

Dicotyledons and Monocotyledons.—The two subclasses of angiosperms are DICOTYLEDONS and MONOCOTYLEDONS. Members of the first group possess two seed-leaves, or cotyledons, in the embryo (Fig. 25); the monocotyledons, one (Fig. 26). This apparently trivial distinction is accompanied by other fairly constant differences in characters. *Dicotyledons have, generally, zonate stems with well-defined bark, cambium, wood, and pith*

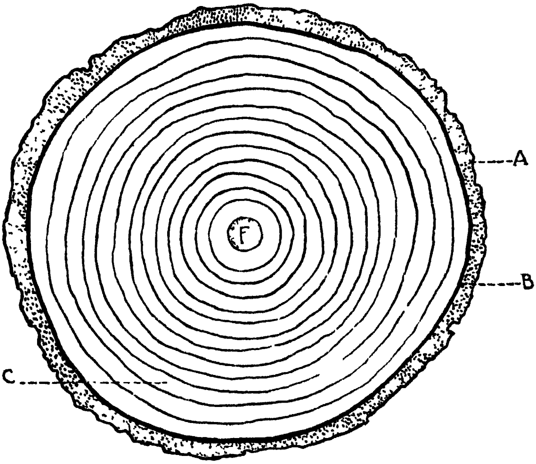

FIG. 27. — Diagram of the Stem of a Conifer or Woody Dicotyledon in Cross-Section. *A*, bark, in which may be the tissues formed in the first and every subsequent year; *B*, the cambium, *C*, the wood, made up of many rings laid down annually by growth of the cambium; the details of conductive tissue and ray are not shown; *F*, pith. (E. Coffman.)

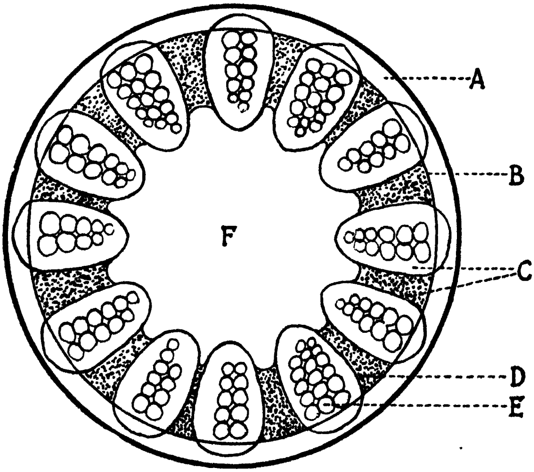

FIG. 28. — Diagram of the Stem of a Herbaceous Dicotyledon in Cross-Section. *A*, bark; *B*, cambium; *C*, region corresponding to the wood of Fig. 27; *D*, ray; *E*, conductive tissue (vascular bundle): *F*, pith. (E. Coffman.)

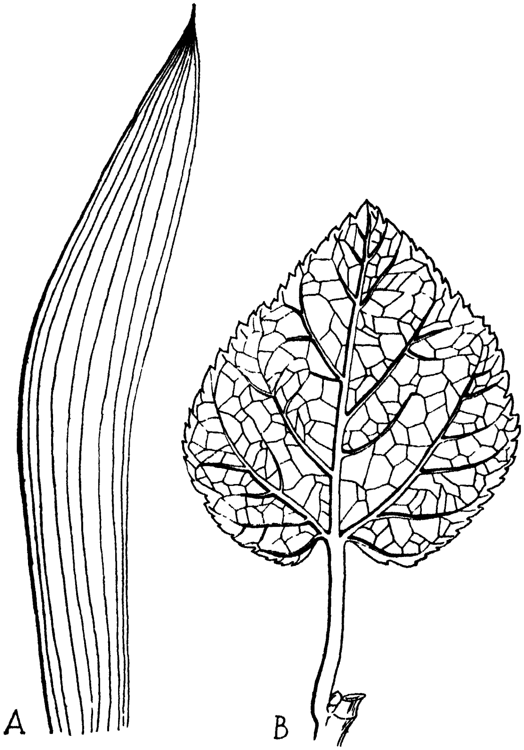

FIG. 29. — *A*, Leaf of Monocotyledon, *Iris*; *B*, Leaf of a Dicotyledon, Mulberry (*Morus*) Showing Veining. (E. Coffman.)

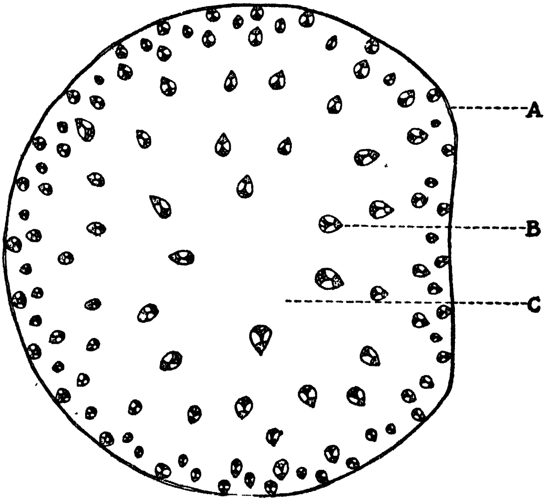

FIG. 30. — Diagram of Cross-Section of a Stem of a Monocotyledon, Indian Corn (*Zea Mays*) Showing Tissue Arrangement. *A*, epidermis; *B*, strand of conducting tissue (vascular bundle); *C*, spongy fundamental tissue of parenchyma

arranged concentrically with the pith at the center (Figs. 27, 28). Those which attain considerable diameter commonly accomplish it by cell-division in the cambium; throughout the growing season, this tissue lays down wood inside itself and bark, in lesser measure, outside itself. Leaves of dicotyledons are usually net-veined (Fig. 29*B*) and are likely to be broad rather than narrow. Flower-parts—sepals, petals, etc.—are apt to be in fours or fives; stamens may be multiples of petal number. Dicotyledons are of great diversity of size and life-duration. They include annual, biennial, and perennial herbs, and nearly all trees which are not gymnosperms. Dicotyledons, in fact, embrace the great majority of the plants of everyday observation; they much exceed the monocotyledons in number of kinds.

Monocotyledons almost invariably lack cambium and characteristic stem-differentiation into bark, wood, and pith zonately arranged (Fig. 30). Leaves (Fig. 29*A*) are commonly parallel-veined and narrow, though orbicular forms of large size are found in the fan palms. With few exceptions, among which the palms (Fig. 31) are notable, monocotyledons are herbaceous plants. In bananas and some other tropical forms they reach a size rarely rivalled by herbaceous dicotyledons. Their flower-parts are commonly in threes; in grasses, sedges, cannas, and orchids, the flowers are greatly modified.

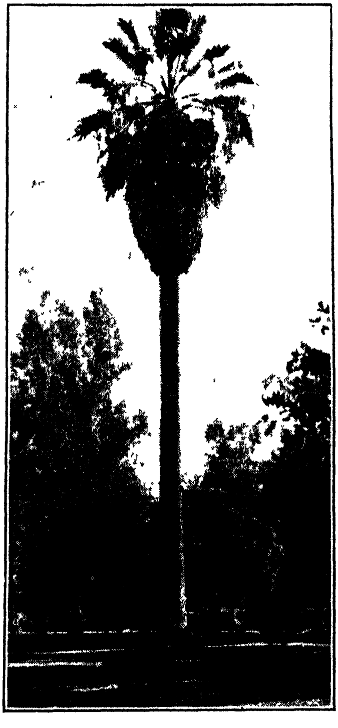

FIG. 31. — The Columnar Stem of a California Fan Palm (*Washingtonia filifera*).

Monocotyledons are most extensively developed in the tropics. The group includes the cereals, the grasses, the bamboos, the palms, the lilies, and many less conspicuous plants. While the monocotyledons are far exceeded in number of species by the other group of angiosperms, they include many indispensable plants. Modern life, lacking cereals and grasses, would need vast rearrangement, and tropical existence without palms and bananas would be far less idyllic than it is pictured at present.

CHAPTER II

CELLS, TISSUES, AND ORGANS

1. THE PLANT CELL

Organisms, both plant and animal, are formed of cells and the products of cells. The existence and the activities of plants and the usefulness of their products to man are directly dependent upon the structure and the contents of plant cells. Therefore, any adequate understanding of the nature and functions of plants and any comprehension of their utilities to the human race must be based upon knowledge of the structure and activities of plant cells and of the substances manufactured within them.

The Structure of Cells

The bacteria and the lower fungi and algæ exemplify the smallest and most primitive plant structures visually known to us. Cells of such organisms are commonly spherical or cylindrical. The more complex bodies of higher plants consist of cells vastly more varied in form by necessities of function and by mutual pressure. The pressure results from close association and from the tendency of living matter to expand. Striking variations of form result from division of labor; each cell reflects in its physical structure its utility to the organism. Cells of the higher plant body can be grouped, rather roughly, into three general types: BOXLIKE or prismoidal, TUBULAR, and FIBROUS. Boxlike cells are likely to be concerned with manufacture or storage, tubular cells with the conduction of materials in solution or suspension, while fibrous cells afford strength and elasticity. A rather more detailed classification of cell-types will presently be attempted. First, however, a rather generalized plant cell may be considered, and some of the common plant manufactures listed and briefly discussed.

A plant cell (Fig. 32) consists essentially of a protoplasmic body or PROTOPLAST. The protoplast is divisible into several components; surrounding it, in almost all cases, is a well-defined CELL WALL. Within the protoplast, and surrounded by it, may be INCLU-

SIONS—non-living, solid, semi-solid, or liquid materials of varied natures.

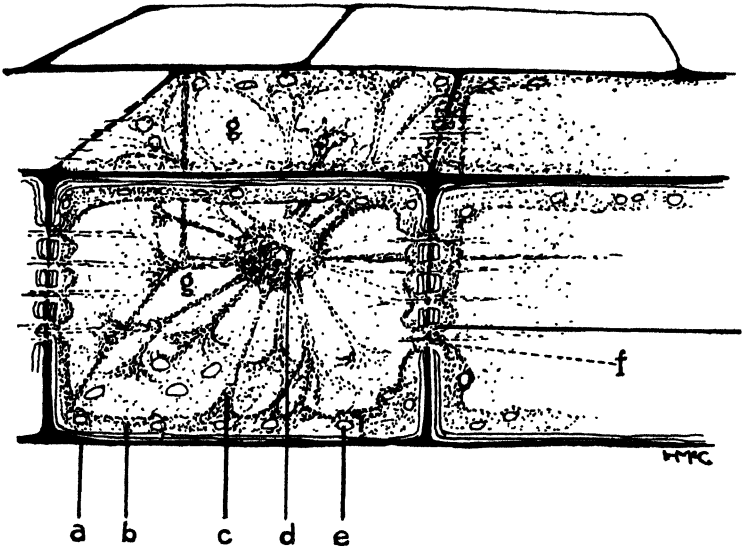

FIG. 32. — Diagrammatic Representation of Plant Cells: *a*, cell wall; *b*, cytoplasm; *c*, cytoplasmic strand; *d*, nucleus; *e*, plastid; *f*, plasmodesma, passing through pit in cell wall; *g*, vacuole. (H. McCarthy)

THE PROTOPLAST

Protoplasmic material is more or less gelatinous in character, containing, while active, a large percentage of water in which are suspended or dissolved many other substances, some of them extremely complex. Attempts to resolve protoplasm into its chemical components are only partially successful; its intricate organization and no doubt the molecular structure of its proteins are destroyed rather than elucidated by analytical methods. We commonly say that the life-secret of protoplasm is in its organization—a statement no doubt true but not very informative. Those highly complex nitrogenous bodies, proteins, are invariably found in protoplasm; they are found nowhere in nature unless formed by protoplasm, and chemical science has been able to put together only a few of the very simplest of them. Associated with them in the protoplast are likely to be carbohydrates, fats, enzymes, vitamins, and substances still less well known. As to the "life energy," that is still more elusive than life-substance. Many of the manifestations of life are bound up with electrical phenomena, and some scientists believe that, if the "secret of life" is ever solved, it will be in terms of electrical energy.

Most protoplasts may be differentiated into NUCLEUS and CYTOPLASM, and each of these components may be resolved into several parts.

The NUCLEUS appears to be essential to the orderly progress of the physico-chemical activities—metabolic processes—upon which the maintenance of life depends. It takes the initiative in ordinary cell division. Within it are the substances which transmit hereditary characters; under their influence offspring resemble parents and ancestors. When the cell is dividing, these substances become organized into bodies, commonly rod-shaped, called CHROMOSOMES. The study of chromosome behavior is one of the most fascinating and one of the most significant branches of biological science, but it cannot be attempted here.

Higher-plant cells not undergoing division generally contain but a single nucleus. In some thallophytes, the plant body is a long tubular cell containing many nuclei.

A nucleus is commonly spherical, ovoid, or lenticular in form. As seen by the microscope, it appears denser than the surrounding protoplasm, from which it is separated by the nuclear membrane. Within it are one or more highly refractive bodies, the nucleoli, whose function is uncertain. The bulk of the nucleus appears granular. By special staining there may be made out a nuclear net, whose strands are of material called linin, upon which are arranged granules of chromatin; the latter is the principal material of the chromosome. Chromatin, linin, and nucleoli are surrounded by liquid, the nuclear sap.

The term CYTOPLASM includes all protoplasmic material within the cell wall save the nucleus and certain other definitely organized bodies, the plastids. In young cells (Fig. 1) nucleus and cytoplasm may fill almost the entire cell cavity. Later, plastids and various non-living inclusions may appear. Delicate cytoplasmic membranes surround the nucleus and line the cell wall. As vacuoles or other inclusions appear, radiating strands of cytoplasm persist, connecting inner and outer membranes.

PLASMODESMA' are tenuous threads of protoplasm which extend through adjoining cell walls, connecting adjacent protoplasmic membranes. They have not been demonstrated in all plants; but it is not improbable that they exist, sometimes on an ultramicroscopic scale, between all adjacent living cells, thus knitting their protoplasts into an organized whole.

The protoplasmic structures called PLASTIDS are generally spheroidal or ellipsoidal in the higher plants, and variously shaped in the algæ. In accordance with function, which is partially manifested through pigments contained, several kinds are distinguished.

CHLOROPLASTS (Fig. 33) contain the green pigment-mixture, CHLOROPHYLL. Thus they constitute the actual photosynthetic machinery of the plant. They contain also, in much smaller quantity, carotinoid pigments. These are yellow, but may form compounds otherwise colored. Vitamin A is a carotinoid or closely related compound (Chapter IX).

CHROMOPLASTS (Fig. 34*A* and 34*B*) contain carotinoids without chlorophyll. They are responsible for the yellow, orange, and some of the red colors of plants. Other reds, and most purples and blues, are due to anthocyans, another class of pigments, which occur in solution in cell-sap.

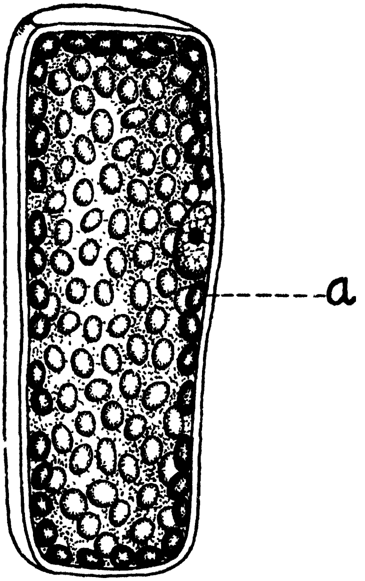

FIG 33 — Stereo Diagrammatic Representation of a Palisade Cell from a Leaf, Cut in Median Longitudinal Section. The chloroplasts (*a*) are arranged in the cytoplasm close to the cell wall. (E. L Spuller)

LEUCOPLASTS (Fig. 34*C*) are colorless plastids commonly found in roots, underground stems, and other structures unex-

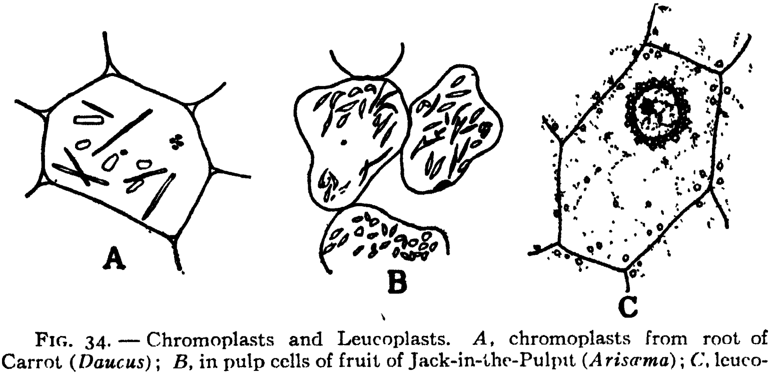

FIG. 34. — Chromoplasts and Leucoplasts. *A*, chromoplasts from root of Carrot (*Daucus*); *B*, in pulp cells of fruit of Jack-in-the-Pulpit (*Arisæma*); *C*, leucoplasts in endosperm cells of Indian Corn (*Zea*). (From Eames and Macdaniels, *Introduction to Plant Anatomy*, McGraw-Hill Book Company, Inc.)

posed to light. Their functions vary; some reconstitute starch from translocated sugars; others manufacture and store oils and fats.

The fundamental organization of plastid-forms is probably the same. Pigment and function largely result from light-exposure, stage of maturity, and other obscure factors. A single plastid may function, in any sequence, as leucoplast, chloroplast, or chromoplast. In tomatoes and oranges, the ovary in the bud contains leucoplasts; later, in the "green" fruit these become chloroplasts; still later, as chromoplasts, they impart yellow, red, or orange to the ripened fruit.

INCLUSIONS

These are of most varied character. They include products formed by various cellular activities—foods, secretions, wastes, etc. Some of them, no doubt, are necessary to the continuance of the life of the cell and of the organism. Relationship to vital activity is suggested by the term ERGASTIC[1] SUBSTANCES which has been applied to them. Among the most common are vacuoles; starch granules; oils and fats; protein-complexes, such as aleurones; crystals; tannins; volatile oils; and many poisonous substances.

VACUOLES are spaces within the protoplast, containing liquid droplets, the so-called cell-sap, consisting of water in which are dissolved various mineral salts, sugars, etc. Vacuoles are most plainly seen in cells which have passed the youthful stage. They are limited by delicate cytoplasmic membranes, permeable to water and to many dissolved substances.

The principal reserve carbohydrate of most green plants is STARCH, a complex substance—or, rather, group of substances in intimate association. Starches of different plants are somewhat variable in composition; the principal constituents are said to be α-amylose and β-amylose—carbohydrates to which the formula $(C_6H_{10}O_5)_n$ is assigned.

Starch is first demonstrable in very small particles in chloroplasts. This *assimilation starch* is soon reduced to soluble sugar and in that form translocated to storage organs—underground stems, seeds, roots, the rays of stems, etc. There it is reconstituted into *reserve starch* by leucoplasts, which generally build comparatively large granules, often of forms quite characteristic of the plant-kind (Fig. 35). X-ray researches indicate that the STARCH GRANULE is crystalline in nature. The gradual accretion of the starch in the leucoplast sometimes results in microscopically visible layering, as in potato starch. Angular granules probably result from crowding. Some starches are thoroughly compacted into compound and aggregated masses, such as occur in rice and pepper.

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[1] From the Greek *erg*—work.

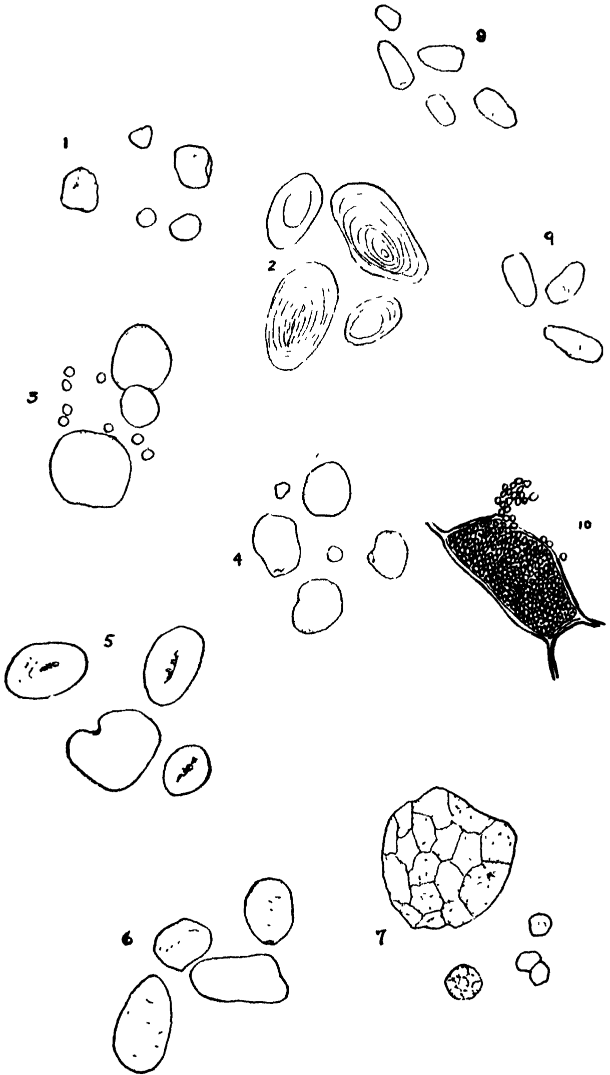

FIG. 35. — Various Forms of Starch Granules. 1, Corn (*Zea Mays*); 2, Potato (*Solanum tuberosum*); 3, Wheat (*Triticum sativum*); 4, Barley (*Hordeum vulgare*); 5, Bean (*Phaseolus vulgaris*); 6, Ginger (*Zingiber officinale*); 7, Rice (*Oryza sativa*); 8, Iris (*Iris* hybrid); 9, Canna (*Canna* hybrid); 10, Pepper (*Piper nigrum*), shown in cell. (H. McCarthy.)

Starch is the principal storage carbohydrate likely to be found in quantity in plant cells.

Sugars, as well as starches, are quite generally present in plant tissue, but usually in relatively small amounts. A few plants, such as the sugar cane and sugar beet, are especially noted for their sugar content.

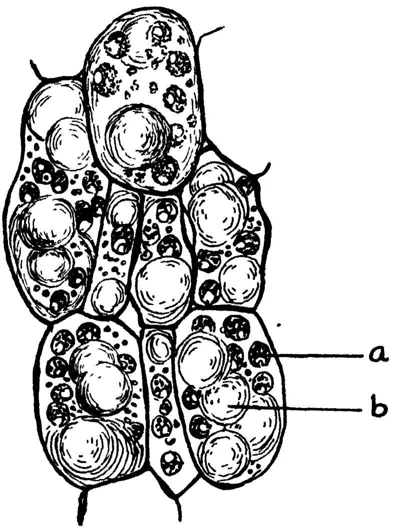

FIG 36. — Parenchyma Cells of Castor Oil Plant Seed (*Ricinus communis*), Showing Aleurones (*a*), and Oil Globules (*b*). (H. McCarthy.)

PROTEINS, it has already been stated, are among the characteristic components of protoplasm. They are also stored in considerable quantity as foods; some seeds, such as that of the bean and most oil-seeds, have very high protein content. *Aleurone grains* (Fig. 36*a*) are perhaps the most familiar forms of protein storage; they are found in vast numbers in the endosperms of castor oil seeds and of cereal grains. They are complex and of variable nature, often containing oil, calcium oxalate, and other substances as well as protein.

Other nitrogenous products are of occasional occurrence. Alkaloids—often very poisonous—and nitrogenous glucosides—of unknown function—occur in various plants.

FIXED OILS AND FATS are found in chief quantity in seeds, some of which, such as the cotton seed, flax seed, various mustards, etc., are commercial oil-seeds (Fig. 36*b*). Oil, being but slightly miscible with other cell contents, usually occurs in droplets. Fixed oils and fats are highly concentrated food substances. They are to be distinguished from volatile oils (Chapter XIV) which are aromatic and generally poisonous compounds.

Calcium salts and sometimes other minerals are to be found in visible form in some cells. Calcium oxalate CRYSTALS of various forms (Fig. 37) are very common. They appear to result from reaction of soluble salts of calcium with oxalic acid, a poisonous substance which results from plant metabolism.

These complex organic substances known as TANNINS are found in almost all green plants, either in solution in cells or in amorphous masses. They occur in quantity in many barks.

Gums, resins, volatile oils, glucosides, latices, and a vast variety of other substances occur more or less commonly in plant cells,

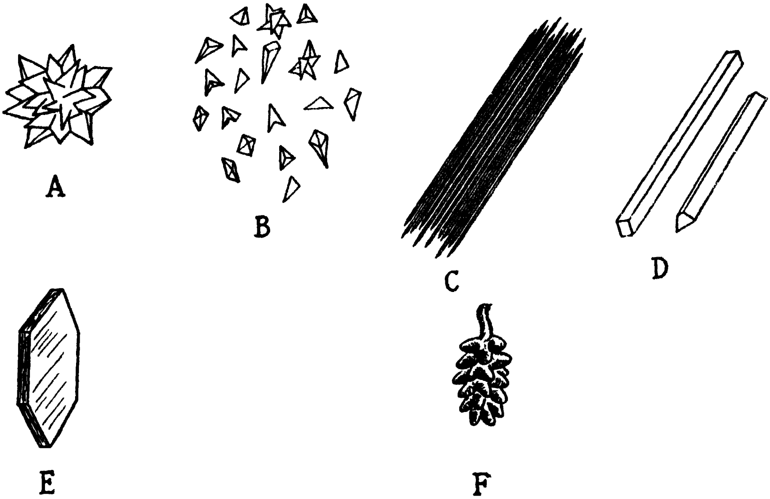

FIG. 37. — Crystals. *A*, rosette from *Euonymus*, *B*, micro-crystals from *Atropa Belladonna*, *C*, raphides from a monocotyledon, *Tradescantia*, *D*, prismatic crystals from *Iris* rhizome, *E*, tabular crystal from *Tilia*, all of calcium oxalate; *F*, calcium carbonate cystolith from *Ficus* In part redrawn from various sources. (E. L Spuller.)

and many of them will be noticed on later pages. Some of them are found in specialized secretion tissue, and some appear to be elaborated as a result of wounds.

THE CELL WALL

Nutritive values of plants are due in the main to cell content. The utilities of wood, pulp-materials, textile fibers, and other constructional materials derived from the vegetable kingdom are due chiefly to the chemical nature and physical character of the cell walls of the products concerned.

Intercellular Layer and Primary Wall.—The composition and structure of cell walls is rather complex, and scientists who have studied their formation are not in entire agreement as to the details of the process. In cell division, adjacent new protoplasts form between them a common membrane, or intercellular layer, of pectic material. Inside this, and often merging indistinguishably with it, each protoplast forms a primary wall of cellulose, a carbohydrate to which is assigned the formula $(C_6H_{10}O_5)_n$.

Pectic material forms a mucilaginous suspension in water. Pectic substances are responsible for the jellying properties of fruit juices; they occur in considerable quantity in unripe fruits and tend to diminish as fruits ripen. In plant tissues generally, the intercellular layer may undergo changes subsequent to its formation.

Cellulose is readily penetrated by water, but is virtually insoluble in it. Hence cellulose walls are highly absorptive and readily transmit water.

The Secondary Wall.—Primary walls, in most cases, undergo secondary thickenings with later deposits.

In very thin-walled cells, no distinction is evident between primary and secondary walls. In its early development, the secondary wall appears to consist chiefly of cellulose and allied carbohydrates. In thin-walled cells, no further change may take place. In thick-walled cells of the mechanical type, addition of another compound (or mixture of compounds), lignin, occurs. The result is a lignified (or ligno-cellulose) wall, of which 60 per cent or more is cellulose and the remainder mostly lignin.

Outer cell walls usually become infiltrated with waxy or fatty substances of complex nature, termed cutin and suberin. Cutinized and suberized cells are virtually waterproof, whereas water and many dissolved substances pass readily through the pectic middle lamella and somewhat less easily through thicker masses of cellulose and ligno-cellulose.

Spiral thickenings are often prominent upon the inner surface of water-conducting cells. Rough manipulation of a plant part, such as occurs in the grinding of drugs, often dislodges them; and they then appear, in a microscopic field, like minute spiral springs.

The Growth of the Cell Wall.—The secondary wall and also spiral thickenings, when present, appear to be formed mainly by a process of centripetal layering, or apposition, from the protoplast. A sort of infiltration of new material amidst old is sometimes seen. The layerings of thick-walled cells are sometimes visible microscopically and can often be made more so by treatment of the walls with reagents.

Recent researches, including investigations with the X-ray, indicate that the cellulose aggregates are laid down in colloidal, ultramicroscopically fibrous particles, which are termed MICELLAE. These seem to be arranged in crystalline patterns which vary in different plants.

Pits.—Secondary thickening is not uniform. Here and there, often in symmetrically patterned arrangement, remain thin areas, usually closed by the intercellular layer and primary wall. These PITS (Fig. 38) are of various forms. They are particularly prominent in conducting cells such as the tracheids (Figs. 49, 50) of gymnosperms. Pits are evidently regions through which liquids may pass more readily than through adjacent thicker areas. Pits of adjacent cells coincide more or less exactly. To complementary pits of adjacent cells, the term *pit-pair* is applied.

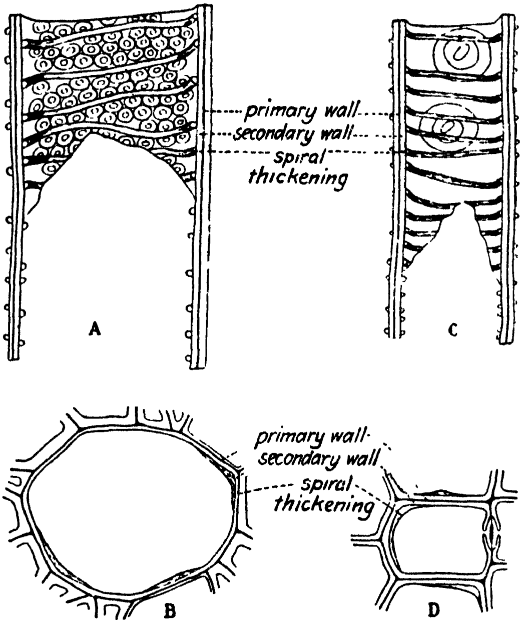

FIG. 38. — Primary and Secondary Walls and Spiral Thickenings. *A*, *B*, longitudinal and transverse sections of vessel of Basswood (*Tilia*), *C*, *D*, longitudinal and transverse sections of tracheid of Western Yew (*Taxus*). (From Eames and Macdaniels, ***Introduction to Plant Anatomy***, McGraw-Hill Book Company, Inc.)

Plasmodesma generally pass through pits.

2. CELL-TYPES AND TISSUES

Division of Labor and Differentiation

Development and elaboration of function concurrent with evolution of higher organisms has induced much variety of structure in cells. For purposes of study, cells may be grouped in fairly natural categories called TISSUES.

Tissues may be considered and classified from various viewpoints, such as that of form—morphological; that of function—physiological; that of origin and development—ontogenetic; and that of grouping and position. As form and function are closely correlated and as form is a visible thing, the usual systems of classification for elementary study are based on form, though their discussion necessitates some reference to their functions. PRIMARY tissue and SECONDARY tissue, terms frequently used, relate to origin and development. Primary tissues are those formed from growing points and regions aside from the cambium or other comparable zonate growing regions. All structures of most monocotyledons and the first formed tissues of conifers and dicotyledons are primary tissues. Secondary tissues derive from permanent growing regions, usually of zonate type and forming a cylinder within the organ possessing them. They make up the principal bulk of large woody conifer and dicotyledon stems and roots, and they are well developed in some herbaceous dicotyledons.

From viewpoint of position, it is logical to divide cell-groupings into SIMPLE tissues—made up of one or at most few closely related cell-types—and COMPLEX tissues—in which associations of various cell-kinds occur together and with correlated functions, as in veins of leaves and other conductive-mechanical categories.

Tissues Classified from the Form-Function Basis

The tissues most commonly recognized are the MERISTEMATIC, the PARENCHYMATIC, the EPIDERMAL, the CORK, the MECHANICAL, the CONDUCTING, and the SECRETORY groups. Like most other humanly devised schemes of cataloguing natural objects, this system is not hard and fast; the categories tend to merge, and some cell-types may *logically* be listed under more than one series. The principal tissue-groups will be briefly described, and further reference to them will be found in the discussions of plant structure throughout the volume.

MERISTEMATIC TISSUE

At or near the extremities of stems and roots; at the zone of division between wood and bark in dicotyledons and conifers; distributed more or less throughout in young leaves, flower-parts, and in many other locations are cell groups which either are in state of active division or are capable of assuming such activity.

These are the meristematic tissues. Their continued multiplication results in dimensional growth. The assumption of various forms by newly divided cells—differentiation—brings about the development of all the various other tissue-systems, and, of course, of the organ and organism in which they are located. Meristematic cells, in general, are thin walled, highly protoplasmic, with large nuclei.

Among the most notable meristem regions are the CAMBIUM (Figs, 55, 57), which builds the secondary tissue of conifer and dicotyledon wood, and the PHELLOGEN or cork cambium (Fig. 44), which constructs cork.

PARENCHYMATIC TISSUE

Parenchyma cells (Fig. 39) are widely distributed in higher plants. Their walls are thin, with little or no lignification; they are generally more nearly isodiametric than other cell-types,

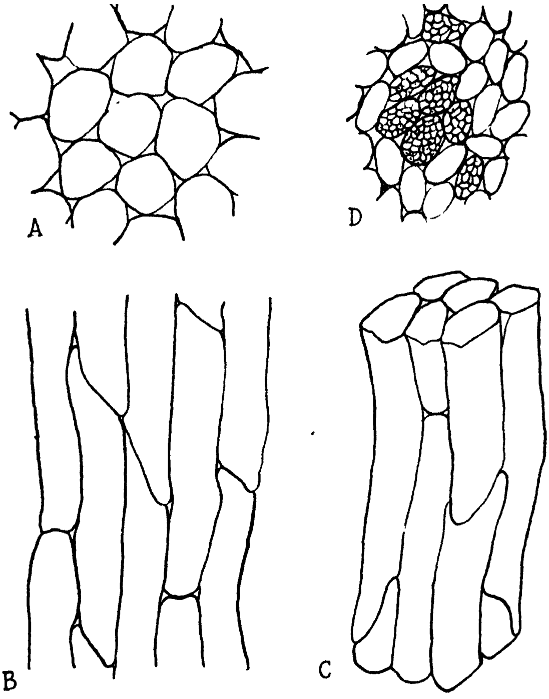

FIG. 39. — Parenchyma. *A, B, C*, transverse section, longitudinal section, and stereo-diagram of pith of stem of Alfalfa (*Medicago sativa*); *D*, transverse section of starch-bearing parenchyma of cortex of root of Aconite (*Aconitum*). (E. Coffman.)

though often elongated in the long axis of the plant part in which they occur. They are frequently highly protoplasmic and long lived; some in bark tissues and elsewhere may retain for a long time the power of meristematic division. While the least specialized of derived tissues, they carry on nearly all the manufacturing and storage within the plant. Some forms serve in conduction.

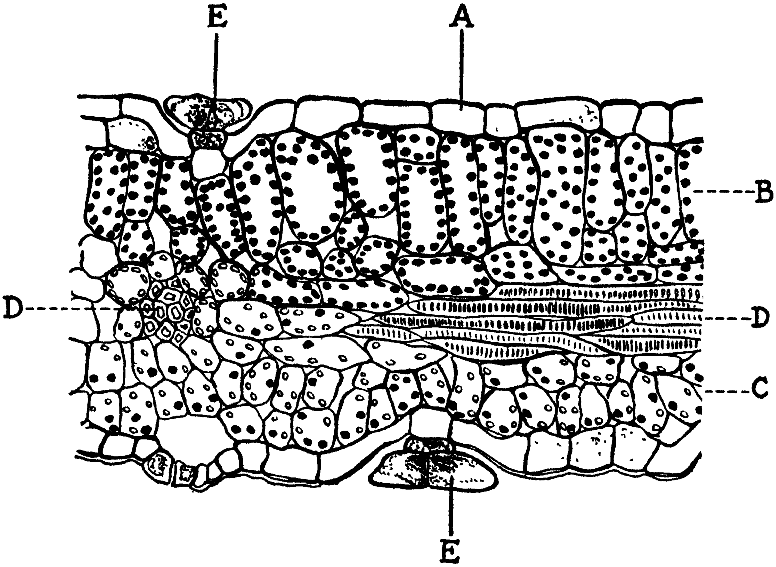

FIG. 40. — A Rather Thin Dicotyledonous Leaf, that of Spearmint (*Mentha spicata*) Shown in Cross-Section. *A*, epidermis; *B*, palisade cells with chloroplasts; *C*, spongy parenchyma, also with chloroplasts; *D*, small veins; *E*, glandular hairs in which the characteristic oil of spearmint is secreted. Photosynthesis is carried on chiefly in the palisade cells; to a lesser extent in the spongy parenchyma. (H. McCarthy.)

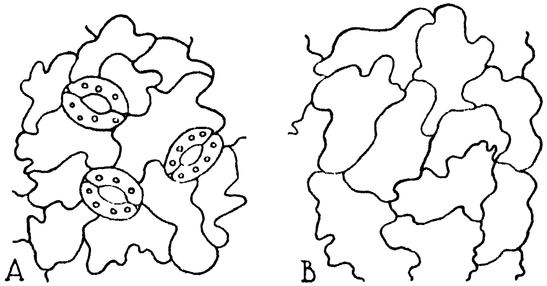

FIG. 41. — Epidermal Cells of Leaf of Plane Tree (*Platanus*). *A*, lower, and *B*, upper, the former showing stomata. (E. Coffman.)

The photosynthetic tissue of leaves (Fig. 40), the softer portions of bark, the fundamental tissue of such monocotyledons as Indian corn, the pith of conifers and dicotyledons, the storage regions of seeds and underground stems, the bulky roots of biennials, the pulpy tissues of soft fruits, and even more or less lignified storage regions of rays and longitudinal parenchyma in wood (Fig. 56), all consist wholly or in major part of parenchyma. In soft or herbaceous plant parts, parenchyma is usually the principal bulk; even hard, tough, and resistant structures often reveal to the microscope a surprising amount of it. Its thin-walled cells, when turgid with water, retain shape well; the contour of most herbaceous plants is maintained by turgid parenchyma, whose water-loss is signalized by rapid wilting. The thin walls of manufacturing and storage parenchyma facilitate the liquid movements and diffusions upon which the life of the plant depends.

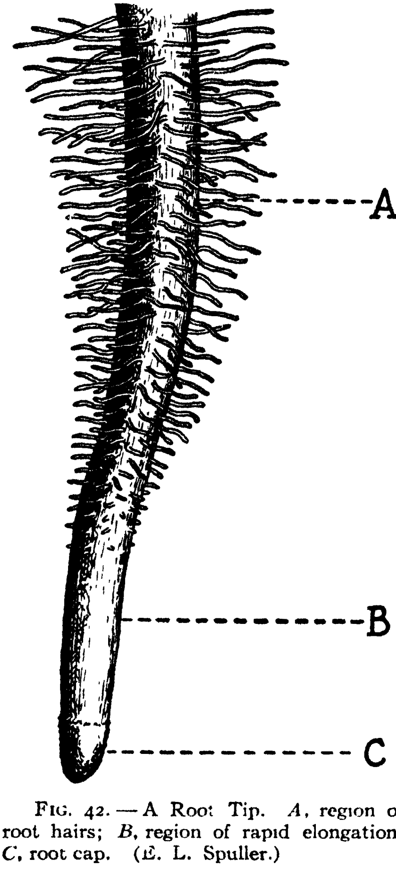

Fig. 42. — A Root Tip. *A*, region of root hairs; *B*, region of rapid elongation; *C*, root cap. (E. L. Spuller.)

EPIDERMAL TISSUE

This forms the outer layer of young roots and stems. In the continued growth of these it is likely to be replaced by cork. Surfaces of temporary structures and organs—leaves (Fig. 41), flower-parts, fruits, seeds, and herbaceous stems—are covered by an epidermal layer which is likely to remain through the life of the organ.

Epidermal tissue is typically a single cell in thickness. With the exception of stomatal openings, the surface of above-ground epidermal tissue is generally covered by a common layer of cutin, almost impervious to water, but slightly permeable by gases, such

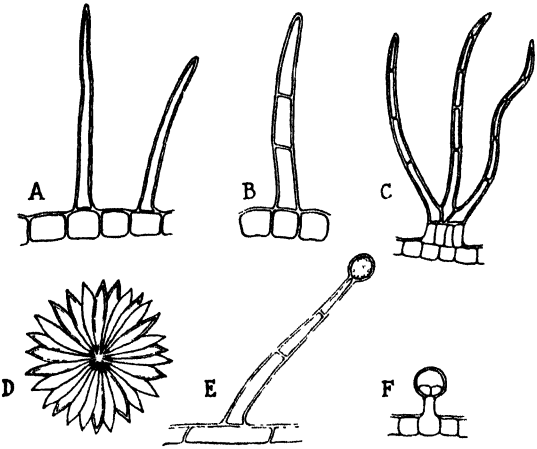

FIG. 43 — Epidermal Hairs *A*, simple hair of *Ailanthus*; *B*, several-celled hair of Foxglove (*Digitalis*); *C*, branched hair of Horehound (*Marrubium*); *D*, peltate hair or scale of leaf of Olive (*Olea*) shown from the top; it is attached by a short central stalk, *E*, glandular hair of *Erodium*, *F*, of *Marrubium*. (E. L. Spuller)

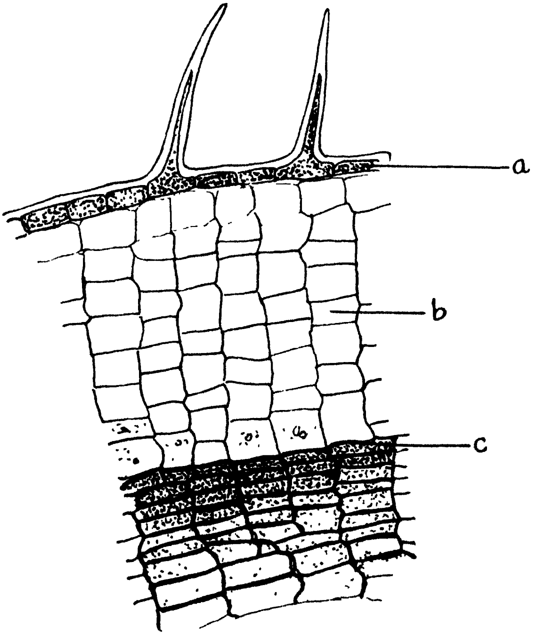

FIG. 44. — Cork Formation in Outer Bark of *Ailanthus* in Transverse Section. *a*, epidermis, with hairs; *b*, cork; *c*, phellogen or cork cambium. Cork and phellogen make up the phelloderm. (H. McCarthy.)

as carbon dioxide. In ferns and shade-plants, chloroplasts may be found in ordinary epidermal cells, but in most epidermal tissue these manufacturing structures are found only in the specialized guard-cells of the stomata (Fig. 41.*1*) which increase and decrease the openings with turgor-changes brought about by sugar-accumulation within them consequent to photosynthesis. Through the stomata, carbon dioxide enters for photosynthesis, and water-vapor leaves the plant in transpiration.

Many epidermal cells give rise to hairs or trichomes. Root hairs (Fig. 42) are specialized absorbing structures, the principal avenues of water-intake. Hairs of above-ground parts give fuzzy, hairy, or felted appearances to leaves and young stems. They are of varied forms (Fig 43); glandular hairs function in secretion of volatile oils and allied substances. Plant hairs are among the cellular elements which retain their character well under pulverizing processes; thus they may serve as indications of identity of powdered substances such as ground drugs.

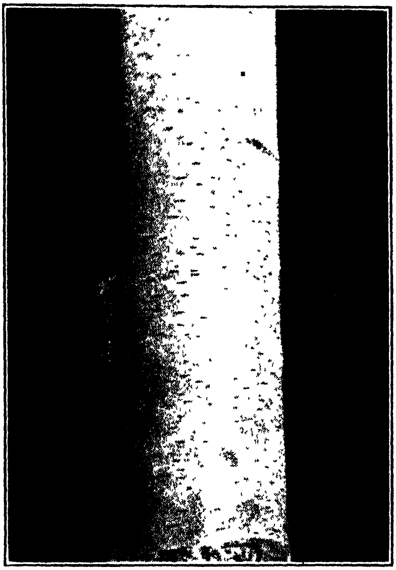
FIG 45. — The Bark of a White Birch (*Betula pendula*), Showing Lenticels.

CORK TISSUE

Phellem or cork (Fig. 44; see also Chapter V) consists of much flattened tabular thin-walled cells, laid down by a meristem called the phellogen or cork cambium. Cork is formed under the epidermis of many woody stems and roots, replacing that structure. Infiltration of the thin walls with suberin renders them among the most waterproof substances in the plant kingdom; it soon results in the death of the protoplast. Respiration-needs of cork-covered parts are met by LENTICELS (Fig. 45), specialized structures of more porous nature which in the first-formed cork commonly develop beneath stomata. In cork of later and deeper origin they are formed by the phellogen beneath cracks in the outer bark.

Cork of most plants is rigid and rather inelastic; that of commerce, from the Cork Oak (*Quercus Suber*), owes its value to its non-typicality in these respects as well as to the profusion in which it is formed.

MECHANICAL TISSUE

Cells which confer rigidity, toughness, and strength to plant body or organ are of several types. In general, mechanical tissue is characterized by relatively thick cell walls, which are usually but not invariably lignified. Protoplasts tend to die early, leaving the skeletal framework of the wall, to the efficiency of which they can contribute nothing after it is completed.

The simplest of mechanical tissues is COLLENCHYMA, which is little more than thick-walled parenchyma, often with special reinforcement at angles. Collenchyma often occurs in ribs on herbaceous stems and frequently makes up much of the bulk of large veins of leaves.

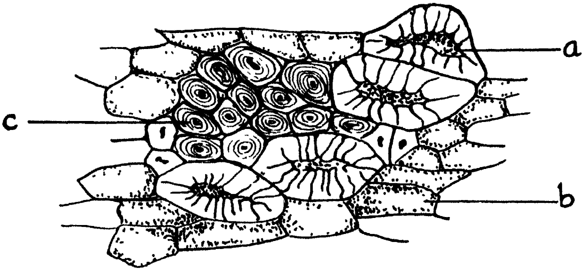

FIG. 46. — Pericycle, from the Middle Bark of *Ailanthus*, in Transverse Section: *a*, stone cells; *b*, parenchyma; *c*, bast fibers. (H. McCarthy.)

The term SCLERENCHYMA embraces more definitively mechanical tissue. Sclerenchyma walls are, in proportion, the thickest of plant boundaries, with the exception of those of some fiber types they are almost invariably strongly lignified. Sclerenchyma includes stone cells and various forms of fibers, the latter being usually classified by location in the plant.

STONE CELLS (Fig. 46*a*) are generally short and "blocky," but may be extended in the long axis of the organ. Elongated types merge gradually with short bast fibers. Stone cells are often characterized by evident stratification of wall and by deep and sometimes branched pits or canals. They make up the bulk of the shells of nuts and of the stone (endocarp) of such fruits as plum and peach. They are common in the barks of woody plants, being there frequently associated with fibers. Barks with many stone cells are hard and brittle rather than tough and flexible. Groups of stone cells lend grittiness to flesh of pears and quinces. They may be found, though not commonly, in leaves; their presence in tea leaves has been used to differentiate the latter from spurious products.

FIBERS are greatly elongated cells, thick walled, usually with pointed or chisel-like ends which "splice by" one another. Groups of fibers lend flexibility, toughness, and, in many cases, springiness to plant parts. Several forms of fibers are shown in Figs. 47 and 48.

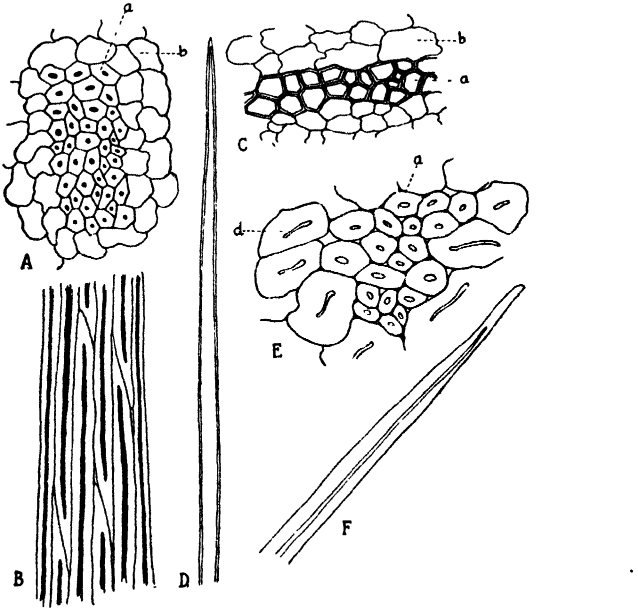

FIG. 47. — Bast Fibers. *A*, the middle bark of Jute (*Corchorus capsularis*), in transverse section, showing (*a*) bast fibers and (*b*) surrounding parenchyma; *B*, fibers in longitudinal aspect; *C*, region in bark of herbaceous stem of Alfalfa (*Medicago sativa*) in transverse section, showing (*a*) bast fibers, (*b*) parenchyma; *D*, extremity of a bast fiber of Alfalfa; *E*, portion of the bark of Saigon Cinnamon (*Cinnamomum Lourierii*) in transverse section, showing (*a*) bast fibers and (*d*) stone cells; *F*, extremity of a bast fiber of Cinnamon. (E. Coffman.)

Fibers occur in the barks of most dicotyledonous trees and shrubs and in those of many herbaceous plants. In this location they are known as PHLOEM FIBERS, CORTICAL FIBERS, and BAST FIBERS. The latter term is often used for any fiber formed outside the cambium. Objections to the usage have been urged, but the expression seems thoroughly established in the fiber-using industries.

Bast fibers of herbaceous plants are often of cellulose or are very slightly lignified. Linen, hemp, jute, and other herbaceous bast fibers are extensively used in textile industry and will be further treated in Chapter VII.

Wood fibers (Fig. 48*a*) of various kinds have been developed by evolution from the tracheid; they make up the principal bulk of the central cylinder of most woody dicotyledons but are absent from that of the conifer. In the latter group the predominating woody cell, the tracheid, is so fiberlike that it is generally termed "fiber" in the pulp industry.

Ribs or bands of sclerenchyma fibers commonly reinforce or surround conductive tissues in monocotyledons. From such strands the textile fibers of sisal, henequen, and abaca are derived.

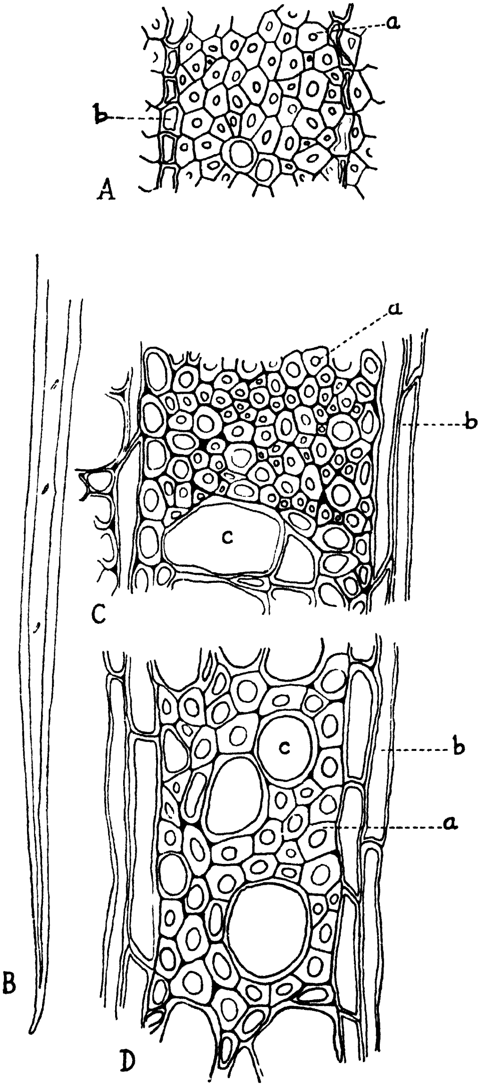

FIG 48. — Wood Fibers and Adjacent Tissues. *A*, wood of White Oak (*Quercus alba*) in transverse section; *B*, extremity of wood fiber of an Oak (*Quercus lobata*); *C*, wood of Elm (*Ulmus americana*), *D*, wood of Red Gum (*Liquidambar styraciflua*); *a*, wood fibers; *b*, parenchyma of ray; *c*, vessels. (E. Coffman).

CONDUCTING TISSUE

As the definitive term indicates, cells of this order serve primarily as avenues of transportation.

The principal types include TRACHEIDS, VESSELS—also known as tracheal tubes—and SIEVE TUBES. All of these elements afford longitudinal avenues of transport in stems and roots; radial conduction is effected in rays, which are radial associations of parenchyma and tracheids. In dicotyledons, rays often include wood fibers.

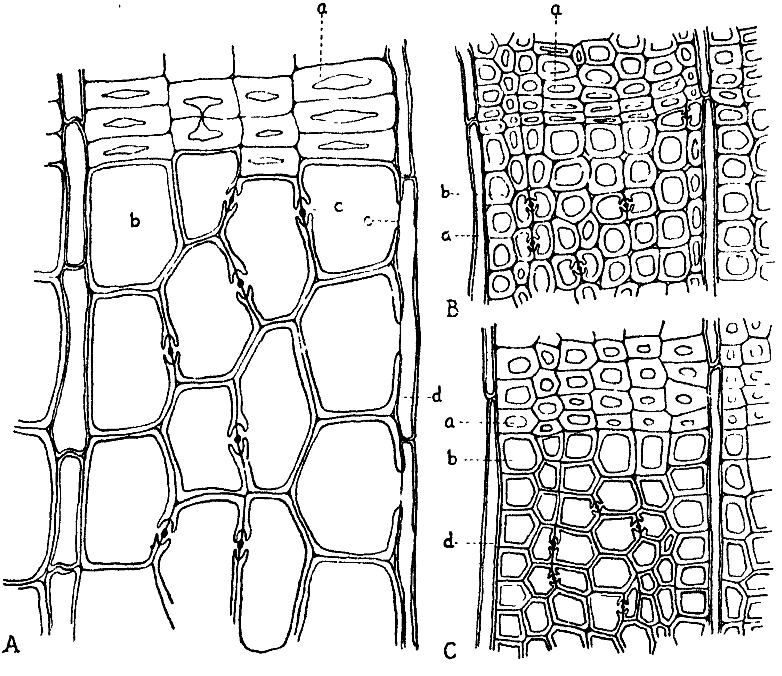

FIG. 49. — Tracheids of Conifers and Adjacent Tissues, in Transverse Sections. *A*, Redwood (*Sequoia sempervirens*); *B*, Red Cedar (*Juniperus virginiana*), *C*, Douglas Fir (*Pseudotsuga taxifolia*). All sections show the junction between summer tracheids of one season and spring tracheids of the next, which marks the limit of the annual ring; *a*, summer tracheids; *b*, spring tracheids; *c*, pits; *d*, parenchyma of ray. (E. Coffman.)

TRACHEIDS (Figs. 49 and 50) are cells of dual nature, combining mechanical efficiency with the water-conducting function. They are fibrous, elongated cells, with tapering, somewhat chisel-like ends; they are usually angular in cross-section, with lignified walls having numerous and prominent pits. Protoplasts of tracheids soon disappear.

Tracheids find their most plentiful development in wood of conifers (Fig. 59), which is made up very largely of cells of this type. Their lignification and thickness of wall (which is particularly notable in those formed late in the growing season) develop a homogenous woody shaft which is, however, generally less dense and strong than the fibrous tissue of dicotyledonous hard-

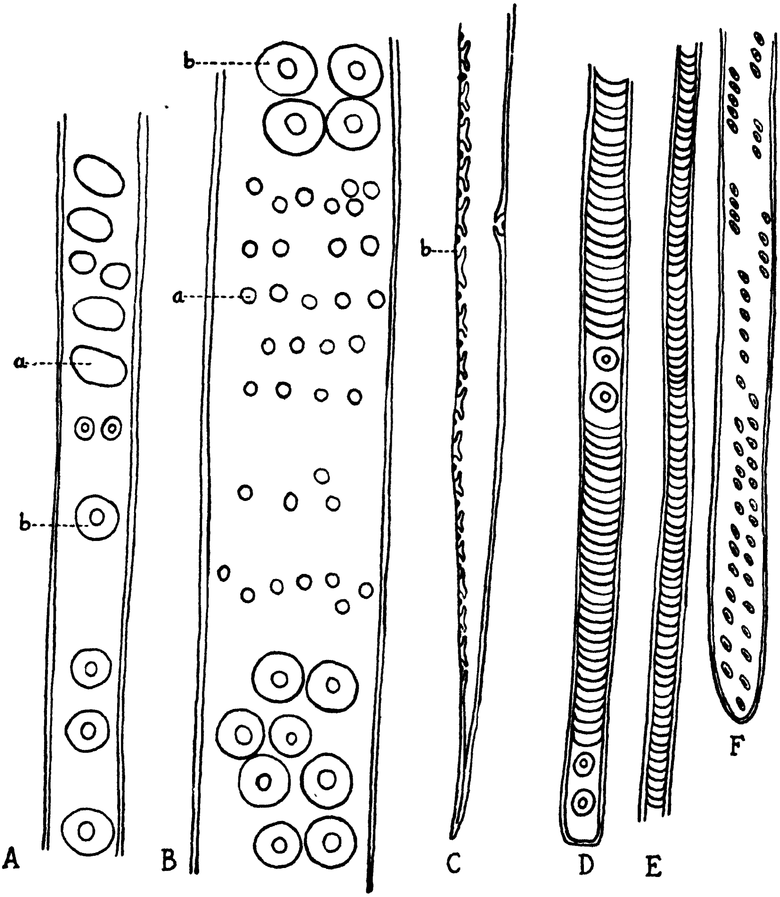

FIG. 50. — Portions of Tracheids. *A*, spring tracheid of Sugar Pine (***Pinus Lambertiana***); *B*, spring tracheid of Redwood (*Sequoia sempervirens*), both in radial view; *C*, extremity of summer tracheid of Redwood in tangential view; *D–E*, spring and summer tracheids of Douglas Fir (*Pseudotsuga taxifolia*) in section, showing spiral thickenings; *F*, extremity of a tracheid of an Oak (*Quercus lobata*); *a*, simple pits, leading into parenchyma of ray; *b*, bordered pits, leading into adjacent tracheids. (E. Coffman.)

woods. The fibrous nature of conifer wood and the ease with which it can be pulped and freed from lignin are among the qualities which give conifer woods, particularly spruce, their preëminence in the paper industry (Chapter VIII).

Tracheids also occur in the wood of the dicotyledon; here they have also further differentiated on one hand to vessels and on the other to wood fibers.

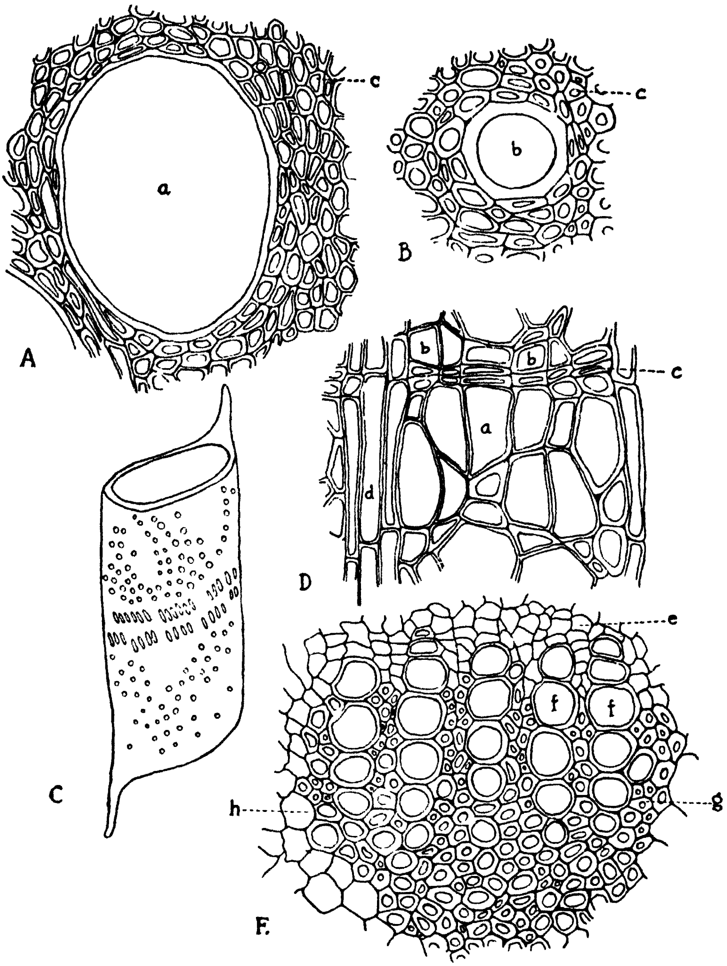

FIG. 51. — Vessels and Adjacent Tissues *A*, *B*, transverse sections of Black Oak (*Quercus velutina*); *C*, vessel of an Oak (*Quercus lobata*); *D*, transverse section of Tulip Poplar (*Liriodendron tulipifera*); *a*, vessel of spring wood; *b*, vessel of summer wood; *c*, wood fibers; *d*, parenchyma of ray; *E*, xylem portion of a vascular bundle of Alfalfa (*Medicago sativa*), showing *e*, cambium; *f*, vessels; *g*, fibers; *h*, parenchyma. (E. Coffman.)

VESSELS (Fig. 51) are the characteristic water-conducting tissues of angiosperms. They are made up of numerous single cells whose adjacent end-walls may be either transverse or diagonally beveled. These end-walls are large-perforate; in some cases they have disappeared. The result is an elongated structure somewhat like a water-pipe with many joints and with very similar functions. Water passes into adjacent elements by means of pits of various types; these pits are generally small and may be very numerous.

Vessels are among the most conspicuous elements in a microscopic field. They are usually cylindrical and often of large diameter. Their inner walls are frequently spirally thickened or ringed. The distribution of vessels in various kinds of wood is one of the principal factors which influence appearance or figure of lumber.

Sieve tubes (Fig. 52*B*), like tracheal tubes, are conductive elements whose tubular nature results from perforations or disappearance of end-walls. While tracheids and vessels are concerned mainly with water-need, sieve tubes are elements of conduction of elaborated foods such as proteins and sugars. They are usually angular structures, having thin cellulose walls with numerous perforations grouped in areas called sieve plates. Sieve tubes remain alive as long as they function. The protoplast is a peripheral layer surrounding a large central vacuole. A remarkable feature of the angiosperm sieve tube is its lack of a nucleus. Adjacent to it and in close protoplasmic connection is a companion cell (Fig. 52*A*), whose nucleus is believed to govern activities in the sieve tube.

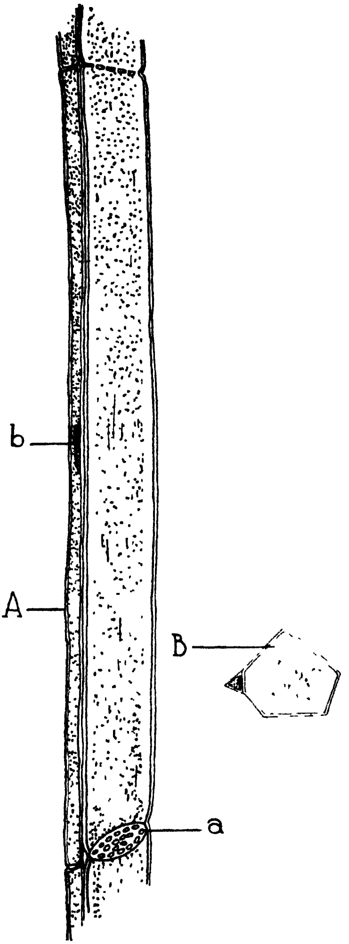

Fig. 52. — Companion cells (*A*) and sieve tubes (*B*) in longitudinal section (left) and transverse section (right); *a*, sieve plate; *b*, nucleus of companion cell. (E. Coffman.)

SECRETORY TISSUES

The terms SECRETION and SECRETORY TISSUE, as used in plant physiology and anatomy, have no very precise significance. Manufactured foodstuffs, crystals, etc., have a certain claim to being listed as secretions, but the expression is usually employed for a variety of other substances, definitely localized in the plant or exuding from its tissues. Among such materials are latices (milky juices, often containing rubber), gums, oleoresins, volatile oils, and nectar. Tissues concerned with the elaboration of these materials are called secretory tissues. Mention has already been made of glandular hairs. The extremities of these are expanded; they may be single-celled or multicellular, and they are of various forms. They secrete volatile oils and sometimes resinous materials; their abundance on certain plants gives the latter a characteristic gumminess and stickiness which is reflected in such terms as "gumweeds" and "tarweeds." Nectaries are often aggregations of glandular hairs which secrete sugars. Most commonly these occur in flowers; sometimes, as in the castor oil plant and cotton, they may be upon leaves.

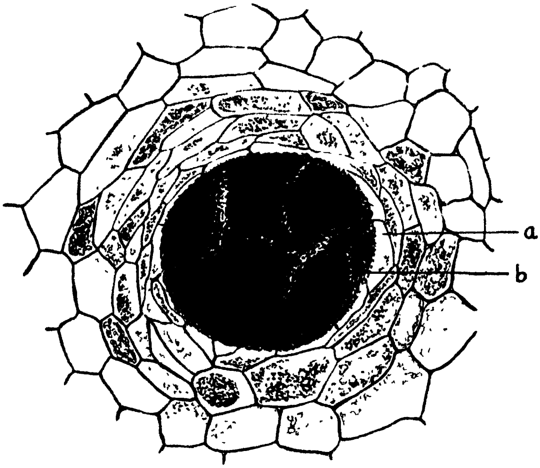

FIG. 53. — Gland of a Seed of Cotton (*Gossypium hirsutum*); *a*, secreting cells; *b*, secretion, composed mainly of a toxic substance known as gossypol. (H. McCarthy.)

Internal secretory tissues include single cells which are little more than specialized parenchyma, glands, oleoresin canals, oil-ducts, laticiferous tissues, etc.

A gland or canal at maturity consists of a central pouchlike structure or elongated tube, surrounded or lined by specialized parenchyma whose secretion is poured within (Fig. 53). Some glands and canals originate in fissures between cells; others, by solution of the cells in which the first secretion takes place.

Digestive secretions are usually not evidently localized in special structures.

Lactiferous tubes are generally complicated, branching structures, anastomosing among other tissues more or less parallel to the conductive systems. These will be noted more particularly in Chapter VI.

Complex Tissues

There are several associations of cell-types which may be briefly mentioned here. The nature of some of them will be made more fully evident in the discussion of various plant products in which they are of significance. Those to be noted now include periderm, pericycle, xylem, phloem, vascular cylinder, vascular bundles, and vascular rays.

PERIDERM

This is a complex (Fig. 44) which commonly replaces epidermis in stems, roots, and occasionally elsewhere, as in "russeted" fruits, etc.. It may consist of three layers: the phellogen or cork cambium, from which the others originate; the phellem or cork, previously described, which usually makes up the principal bulk of the periderm; the phelloderm, a loosely arranged group of various elements laid down by the phellogen inside itself.

Periderm development varies greatly in different trees. The outer bark appearance, in such tree-kinds as the plane trees, the shagbark hickory, the beech, and the eucalypti reflects variation in periderm development.

PERICYCLE

This (Fig. 46) may include parenchyma, stone cells, and bast fibers, in mixed or zonate arrangement. The harder tissues are likely to predominate in the bark of stems. In the root, the pericycle is likely to be of parenchyma which retains its meristematic potentiality; it serves as point of origin for branch roots which start before cambial activity begins.

XYLEM

Xylem (Fig. 51*E*) is a woody conducting and mechanical complex whose essential element is the tracheid. In angiosperms the xylem is formed of vessels, tracheids (if present), wood fibers, wood parenchyma, and the intra-cambial portions of the rays. It constitutes that major portion of the conifer or dicotyledon stem known as wood. Its elements are the water-conducting and strengthening tissues of the vascular system, including the veins.

PHLOEM

This tissue is usually found in definite association with xylem. In the conifer and dicotyledon stem, its common position is outward and across the cambium from the xylem. The essential element is the sieve tube; companion cells, parenchyma, and sometimes fibers occur. Grouped associations of these tissues are frequently separated by extra-cambial or phloem portions of vascular rays.

VASCULAR CYLINDER AND VASCULAR BUNDLES

Morphological researches, and the study of ancient plants whose remains are preserved as fossils, indicate that the ancestors of our present seed-plants, like the trees of our own day, possessed a compact central column, or VASCULAR CYLINDER, with heavily lignified xylem separated from a surrounding phloem-

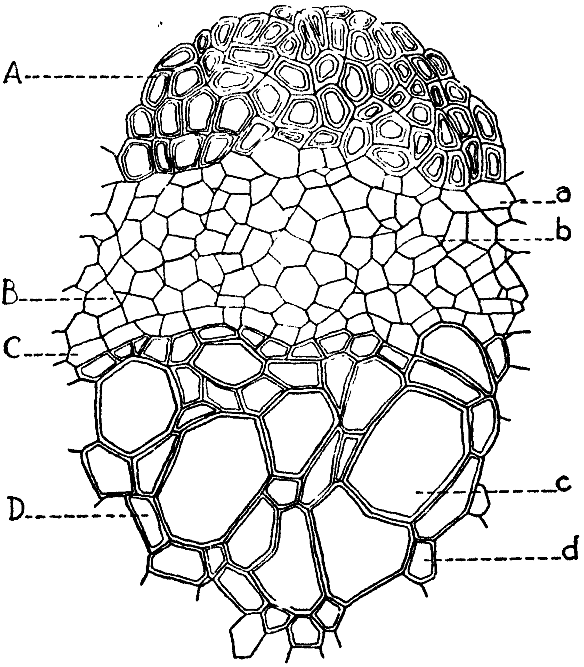

FIG. 54. — Vascular Bundle of a Dicotyledon, the Pea (*Pisum*). *A*, mass of bast fibers; *B*, phloem; *a*, sieve tube; *b*, companion cells; *C*, cambium (scarcely differentiated); *D*, xylem; *c*, vessel; *d*, wood parenchyma. (E. Coffman.)

ring by a band of cambium. These ancient woody plants developed, it is believed, in a climate of perpetual summer, when growth continued throughout the year. Development of seasonal changes in climate, with consequent interruptions of the formerly continuous growing-period, brought about profound changes in plant types and plant structures, the discussion of which cannot be attempted here. In reaction to the necessities of short-season life, the herb developed—a plant capable of producing seed upon above-ground parts which last but a single growing season.

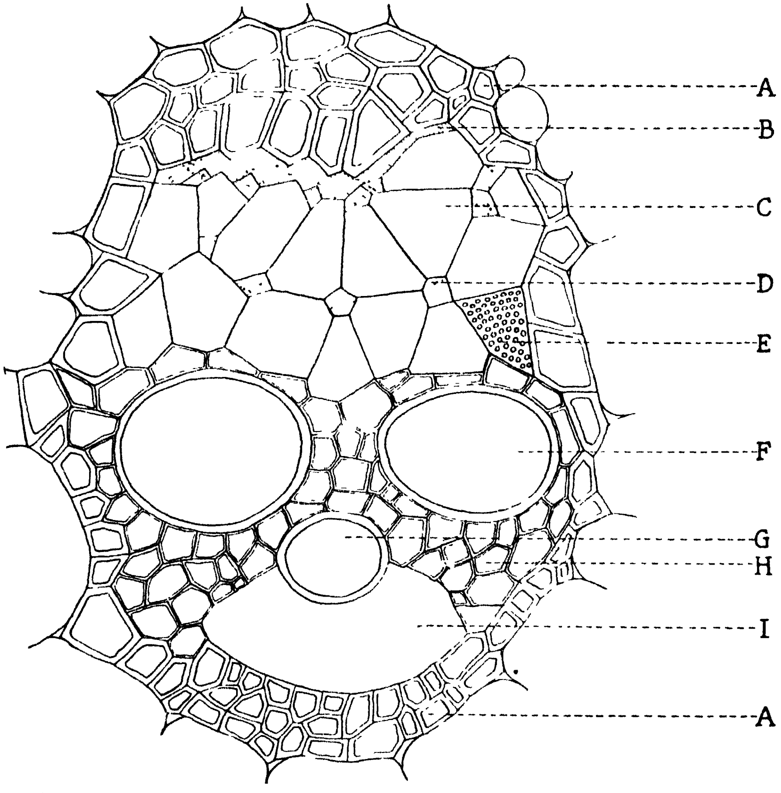

FIG. 55. — Vascular Bundle of a Monocotyledon, Indian Corn (*Zea Mays*). *A*, fibers, in sheath surrounding the vascular tissues; *B*, early phloem or protophloem, crushed by expansion of tissues of later formation; *C*, sieve tube; *D*, companion cell; *E*, sieve plate in end-wall of sieve tube, all of the phloem; *F*, pitted vessel; *G*, annular vessel; *H*, tracheid, of the xylem; *I*, intercellular channel formed by uneven expansion of surrounding tissues. (E. Coffman.)

In many herbaceous dicotyledons and in monocotyledons, xylem and phloem aggregates extend in closely aligned complexes called VASCULAR BUNDLES (Figs. 54 and 55). The frequent association of fibrous mechanical tissue with these conductive strands has given rise to the term *fibro-vascular bundle*. In most stems of herbaceous dicotyledons the conductive elements of xylem and phloem are separated by cambium, and the bundles themselves are separated by broad RAYS which function as storage-regions.

Vascular bundles are essential elements of the veins of leaves.

VASCULAR RAYS

These are among the most striking cell-associations of conifers and dicotyledons, particularly of the latter. They consist of narrow aggregates of cells, of no great depth and spindle-shaped in tangential view, extending in a radial direction across the cambium (in which they originate) at right angles to the direction of growth of stem or root (Fig. 56).

The xylem portion of the ray, lying within the cambium, consists characteristically of parenchyma cells whose long axes are in the radial direction. In the phloem region the cells are often shorter. Rays of conifers are limited above and below by specialized ray tracheids.

Vascular rays serve as avenues of radial conduction in stem and root and also as storage reservoirs for starch and other foodstuffs.

3. ORGANS OF THE SEED PLANT

A seed-plant organ, in the common usage of the term, is a definite and well-defined part in which, under usual conditions, certain characteristic functions are localized. The organs commonly recognized are the vegetative organs—STEM, ROOT, and LEAF—and the reproductive organs or organs of perpetuation—FLOWER, FRUIT, and SEED. Among the first group are distributed the tasks which enable the plant to maintain itself as an individual; the latter have to do with the continued existence of the species.

Primary Activities of the Plant

Among the activities characteristic of the living plant as a whole are anchorage; absorption; mechanical support of its own structure; conduction of water, raw materials for food manufacture, food, and other metabolic products; metabolic activities, food production and utilization; the storage of food, water, or raw materials; self-protection; and regeneration. These functions are to some extent generalized throughout the whole system; but they tend, in various degrees, to become localized in and specially characteristic of the various organs and organ modifications.

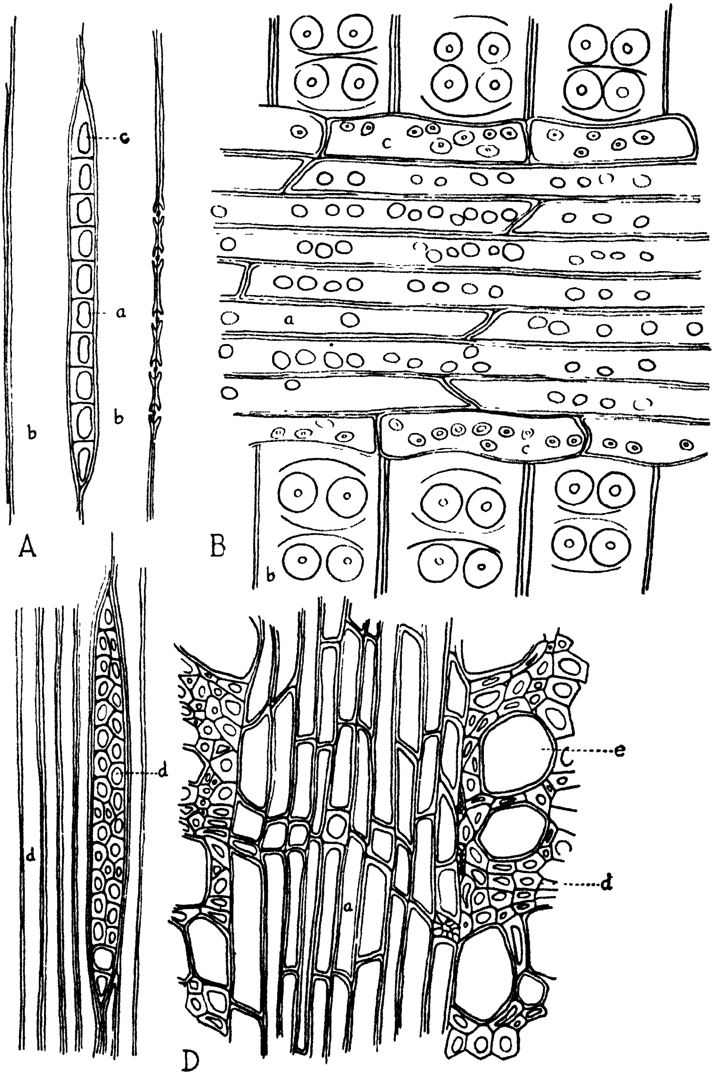

Fig. 56. — Xylem Portions of Vascular Rays and Adjacent Tissues. *A*, *B*, tangential and radial sections of Redwood (*Sequoia sempervirens*); *C*, tangential section of Black Walnut (*Juglans nigra*); *D*, transverse section of Plane Tree (*Platanus occidentalis*); *a*, parenchyma of ray; *b*, tracheid; *c*, ray tracheid; *d*, wood fiber; *e*, vessel. (E. Coffman.)

Occasionally any organ may be modified from its usual form or character. In that case it generally loses its normal functions; it may or may not take on others. Leaves of the asparagus have become vestiges; photosynthesis is carried on in the stem. Roots of some epiphytes—plants which grow on other plants, as tropical orchids on trees—have become green and carry on photosynthesis. But, generally, roots, stems, and leaves are so characteristic as to be readily recognizable.

Functions of the Vegetative Organs

THE STEM

This forms an evident support for leaves and flowers and is obviously the only means of communication of these organs with the root. In so far as it is chlorophyll bearing as are most herbaceous stems and the current season's growth of many woody ones, the stem is a photosynthetic organ. Many perennial stems store food; this function is especially developed in the underground stems of herbaceous perennials. Annual plants have little need of food storage in any vegetative organ.

A somewhat diagrammatic representation of the cells and tissues of woody dicotyledonous stem is afforded by Fig. 57. The function of support is in stems commonly served by masses of thick-walled wood fibers or tracheids; the walls of vessels are often thick enough to be of some slight mechanical value. Mechanical efficiency is also promoted by the usual arrangement of woody elements in cylindric form, and the constant increase of the woody cylinder of the cambium-forming conifers and dicotyledons makes it possible for these to achieve massive and branching forms not attainable without secondary growth.

Bark tissues effect conservation of the water-stream through cutinized epidermal tissues and suberized periderms. The mechanical tissues—stone cells and bast fibers—of the pericycle afford resistance against wounding and bruising of the delicate cambium without being so resistant as to constrict the constant expansion which comes from its cell division. Barks of most trees are furrowed or shaggy from the breaking of outworn and overstrained outer layers whose functions have been taken on by new tissues. The principal conductive activity of bark—that of transportation of elaborated food—requires much less tissue bulk than that needed to supply the incessant water demand which the xylem serves; the active phloem is generally a narrow band of comparatively few layers of sieve tubes and associated tissues.

Storage in woody stems is carried on mainly in parenchyma of bark and wood; in the latter zone ray parenchyma is usually the chief storehouse. Underground stems, such as the rhizomes of monocotyledons—grasses, iris, canna, and the like—belong usually to comparatively small plants; from this, and because of their location, need for mechanical strength is not great. Frequently their principal bulk is starch-bearing parenchyma. Many such stems are utilized as food for men and animals; the potato tuber is a special underground stem modification produced by the plant for the dual purposes of storage and perennation.

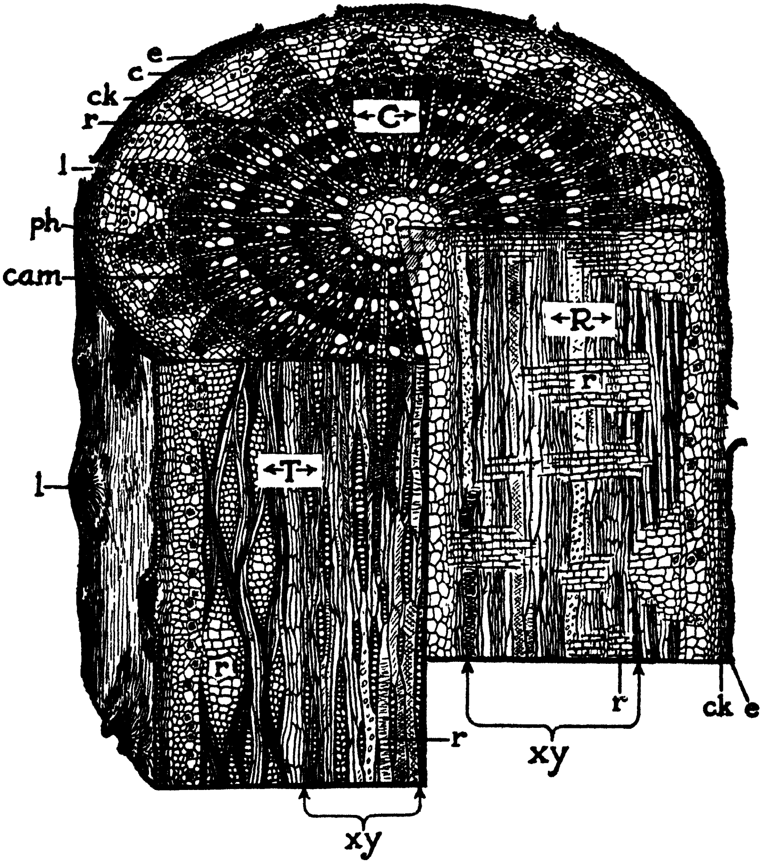

Fig. 57. — Stereo-Diagram of a Three-Year-Old Stem of Basswood (*Tilia*). *C*, transverse section, *T*, tangential section; *R*, radial section; *e*, epidermis; *c*, cortex; *ck*, cork, *r*, vascular ray; *l*, lenticel, *ph*, phloem; *cam*, cambium; *xy*, xylem. (From Hansen in Curtis, *Nature and Development of Plants*, Henry Holt & Co.)

THE LEAF

The leaf is the principal photosynthetic organ of the plant. Both the absorption of solar energy and the intake and outlet of gases are facilitated by the flattened form, which exposes a relatively enormous surface per unit of weight or bulk. Some of the tissue arrangements of the leaf of a dicotyledon are shown in Fig. 58.

The upper epidermis is generally cutinized and lacking or scantily furnished with stomata. Beneath it are the cells principally concerned with photosynthesis, the palisades. These are generally prismoid or short-cylindrical, with the long axes at right angles to the plane of the leaf surface. The numerous chloroplasts are disposed in the cytoplasm close to the walls. In leaves which are held vertically, including those of grasses and many other monocotyledons, there is usually less differentiation of photosynthetic tissue; characteristic palisades may be lacking. In some vertical leaves, palisades line each surface. Thin leaves have generally a single palisade layer; thick ones, including many evergreen forms, may have several. Beneath the palisades is a mass, usually several layers deep, of loosely arranged spongy

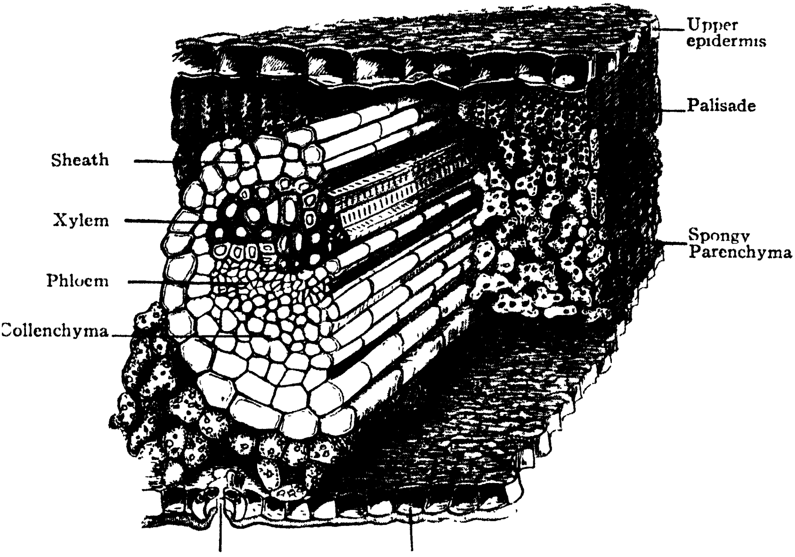

FIG. 58. — Stereo-Diagram of a Portion of a Leaf, Including a Fairly Large Vein. (H. McCarthy)

parenchyma, less plentifully furnished with chloroplasts. The intercellular spaces of this region communicate with the large openings over stomata and with smaller spaces between palisades; the green tissue of the leaf is thus furnished with a catacomblike system of passages by means of which carbon dioxide and oxygen pass through the thin moist cell walls according to the needs of photosynthesis and respiration. The guard-cells of the stomata carry on photosynthesis and expand and contract according to the amount of sugar formed within them. With sugar increase, they expand, drawing back the thin walls which face the stomatal opening, thus increasing the possibility of carbon dioxide intake and, concurrently, that of water-loss. Stomata are the principal outlets of water. Water-loss in plants is termed transpiration.

The veins of leaves are essentially continuations of the xylem and phloem tissues of the stem, which carry on here the same functions of conduction. The mechanical efficiency of the vein is often increased by a fibrous bundle-sheath and frequently also by masses of turgid parenchyma and collenchyma below the conductive tissues.

Storage is not commonly a leaf function, but the scales of bulbs and the foliage of succulent plants retain considerable quantities of water and some other food materials.

THE ROOT

The root is the organ of absorption and the principal organ of anchorage. In biennials and perennials it usually serves to some degree as a storage reservoir. Roots, particularly main roots, tend to resemble the stem-types which they accompany, with some differences in detail. While stems tend to be columnar, massive, and relatively little branched, exigencies of life and function in the soil are likely to develop slender, much branched, intricately ramifying underground systems. Massive growth, when it occurs, has to do with storage.

Figure 42 has indicated something of the outward appearance of a very young root. At the apex a root cap serves as a buffer as the delicate dividing tissues of the region of elongation thrust it through the soil. Directly back of the elongating region is a zone of numerous tiny root hairs, through which most of the absorption of the plant takes place. As the root continues to grow, root hairs are constantly produced behind the growing point; and those of older regions, left farther behind, as constantly die. Thus the root, as it advances, finds new sources of soil water and mineral nutrient. Inside the root, water passes through the parenchymatic region of the cortex and eventually reaches the vascular system, which is continuous with that of the stem. While the roots of large trees are often several inches in diameter, the wood-development of the underground system is likely to be much less extensive than that of the stem. Save in monocotyledons, where there is a small pith or woody-pith center, parenchyma is often lacking in the center of the root of the seed plant. In storage-root types, as in the dahlia and cassava, masses of parenchyma may receive food and water. In some cortices of shrubs and trees, also, is much storage parenchyma.

Roots of primary growth branch from the pericycle. Roots of secondary growth occasionally branch from the cambium.

Flower, Fruit, and Seed

Something of the nature and gross structure of the flower has already been indicated. Flower-parts—sepals, petals, stamens, and pistils—are all leaf-modifications, although the leaflike nature of stamens and pistils is scarcely evident at first glance. As to cellular construction, sepals and petals are generally built upon a leaflike plan; the latter, in showy flowers, lack chlorophyll and the internal structure is mainly of little-differentiated parenchyma. Stamen-construction is largely parenchymatic, with sufficient conductive tissue to supply water-needs. The pistil and the fruit which develops from it are variable structures. Tissues of ripe fruit run the entire gamut from extreme succulence to extreme lignification. Often, tissues, texture, and appendages which the ripe fruit may possess have directly to do with seed dispersal. Many-seeded fruits generally fall into two types: DEHISCENT fruits, like the pods of beans and peas and the capsule of cotton, and INDEHISCENT fruits, of which extreme types are the close-coated caryopsis or grain of corn or wheat, the hard achene of the buckwheat, and the soft fruit of the cranberry and cherry.

Dehiscent fruits are generally hard-shelled; their tissues shrink unevenly upon drying, with consequent rupture along lines of weakness. The grain and the achene are also hard-shelled or tough-shelled; each contains but a single seed and rupture is therefore scarcely necessary. Berries and stone-fruits like the cherry are made up mainly of juice-filled parenchyma, attractive to animals. Their seeds, which are hard-shelled, resist digestive processes and so are likely to be scattered in the dejecta of birds and other organisms which feed upon them.

The inner tissues of seeds—those of embryo and endosperm—are likely to be largely of thin-walled parenchyma, highly food-charged. Those of the embryo retain meristematic power of division. Continued viability of the seed is likely to be conditioned, to a considerable extent, upon the structure of the seed-coats or upon their reinforcement (in single-seeded fruits) with the wall of the pericarp. The seed-coat or pericarp wall has the double task of being sufficiently retentive of water to prevent death of the delicate tissues within by desiccation yet sufficiently pervious to allow the ingress of water necessary to germination. In general, seeds retain their viability but a few years; some, like those of the willow, lose power of growth very soon after being shed. Some very small and hard-shelled seeds, like those of purslane, pigweed, and other common weeds, retain viability in the soil for twenty to thirty years. Fruits of the lotus have germinated after having been buried in the peat of swamps for at least 150 years. Tales of the growth of "mummy wheat" from Egyptian tombs, however, are circulated by Sunday-supplement writers and not by scientists.

CHAPTER III

FOREST PRODUCTS: WOOD, TIMBER, AND LUMBER

1. FOREST PRODUCTS

The forest has ever been of prime significance in the life of primitive man and his more or less civilized descendants. Even while standing, a forest is shelter of a sort; for countless ages trees have also given refuge to climbing and flying animals and have scattered their fruit both for quadruped and biped. Presence or absence of forest has profoundly modified dawning cultures of African, Tartar, and Eskimo; of early Egyptian, Greek, and Roman. Hiding adversary and ally, sheltering Indian and wild beast, covering fertile soil offering mast and roof-tree for the taking—the primeval-forested Appalachian range rose darkly before the early colonist. His descendant, bursting through on the prairie some generations later, scarcely knew how to comport himself in a land where no forests were.

The early colonist thought the forest inexhaustible—something to be cleared from valuable land while saving such building material and fuel as the moment needed. Ten generations of such thinking has brought us to a point where many valuable tree-species are all but extinct, where conservation of the forest as an asset and as a playground is a necessity not merely of the future but of the present. So much—so necessarily—we think of forest conservation to-day that we scarcely realize that a few decades ago the very phrase was a novelty.

In summing forest uses, one thinks first of building materials—of wood, timber, lumber; then of fuel; then, perhaps, of wood pulp. Tanning materials, naval stores—rosin and turpentine—wood distillation products, and such specialties as maple sugar, come less readily to mind. From forests have come our shade trees and landscape trees; from wild lands our apples, pears, and oranges. From tropical forests, resins and gums, rubber, cork, dyewoods, and medicinals such as cinchona, source of quinine.

Not only does the forest serve as source of direct supplies; its presence ameliorates climate. It regulates run-off of water, which tends to prevent spring floods and to conserve water supply throughout the season for the commerce of rivers, for water-power, for agriculture, and for the drinking supply of cities. Its roots hold soil against erosion. Its branches shelter our vanishing wild game and the streams in which fish breed. It offers homesite and food and building material to the birds which, better than all the poisons of the chemist, protect our farm crops and the forest itself against insect waste. The forest enhances the value of mountain and non-arable land for resorting and for vacationing. All these are economic values and notable ones, yet they can receive but bare mention here.

2. Wood, Timber, and Lumber

These terms have various shades of meaning and to some extent are used interchangeably. Wood—"woods" in the United States—is often used synonymously with forest. As applied to material, wood usually denotes the lignified portion, chiefly composed of secondary xylem, which is found within the cambium ring of gymnosperms and dicotyledons. Timber may mean either standing forest growth of merchantable character, or beams, posts, and other comparatively large structural units cut and shaped for building purposes. The term lumber, which is in common use especially in the United States and Canada, includes timber in the second sense, and in fact all prepared or semi-prepared wood intended for construction or manufacture. The lumber of commerce is almost wholly derived from the main stems of trees; branches, an important source of fuel, are usually too small and too tortuous for sawing, and even more so are woody roots, which, moreover, are scarcely easy of access.

Monocotyledons are for the most part plants of small size. Even in the larger palms, yuccas, bamboos, etc., the lignified material lacks the concentration and arrangement which renders so valuable that of other trees. While the trunks and petioles of palms and the stems and branches of bamboos find much structural employment in the tropics, and while the bamboos and rattans—because of their flexibility—are indispensable in the manufacture of some articles of furniture, baskets, and the like, the monocotyledons in general do not enter the world's lumber trade and therefore will not be further considered in the present connection.

The Composition of Wood

It has already been indicated (Chapter II) that wood is made up chiefly of elongated cells in whose walls are found cellulose and a complex substance or mixture of substances termed lignin.

Despite much research on the subject, it is still uncertain whether lignin is a chemical compound or a mixture of compounds and whether its association with cellulose in wood is chemical combination or merely mixture. By those who consider it a compound, the formulas $C_{36}H_{44}O_{14}$, $C_{36}H_{40}O_{12}$, and $C_{40}H_{42}O_{11}$ have been proposed. Dry wood contains about 60 per cent of cellulose and 20 to 25 per cent of lignin. The cells of wood, like those of other plant products, are cemented together with pectic substances. A considerable variety of other organic substances—dyestuffs, tannins, resins, gums, etc.—are found in wood, as well as calcium oxalate and other mineral compounds, whose residues are left after combustion as ash. The ash content of wood is generally not over 1 or 2 per cent.

The Structure of Wood

THE CELLULAR NATURE OF WOOD

With the exception of those of the rays, vessels, etc., which make up a comparatively small proportion of the bulk of most timber materials, wood cells are more or less fibrous structures, elongated in the direction of the long axis of trunk or branch. The cellulose-lignin content of their walls imparts to wood a considerable degree of strength and rigidity, both very closely dependent upon the size of the elements and the relative thickness of cell walls. Wood, also, is flexible (particularly when water-soaked) and elastic. The elongated cavities of the cells, which in wood of living trees may contain the watery substance called sap, in dried wood become air-cavities. Wood, then, is to a high degree both fibrous and porous, and to these characters is due much of its value as structural material.

As chemical analysis indicates only slight differences in the character of the cell-wall substance of different woods, it is evident that, when dry, the great variations in their specific gravity, hardness, and strength are almost wholly dependent upon the character and shape of the cells of which they are composed, particularly upon their length and the relative thickness of cell wall and size of cavity. Light, easily cut, and weak woods—such as white pine, willow, and the lindens—are made up of thin-walled elements of considerable size, with large cavities; while the heavier, harder, and stronger substances of oaks, hickories, and mahoganies consist chiefly of long, thick-walled fibers of small cavity, which may be interspersed, it is true, with very large water-conducting elements. In a few species—such as ebony, rosewood, and some pines—resinous or gummy material, permeating cell walls and filling cell cavities, may add appreciably to the weight of the wood. That even the heaviest of ordinary woods include considerable pore space may be inferred from the fact that the

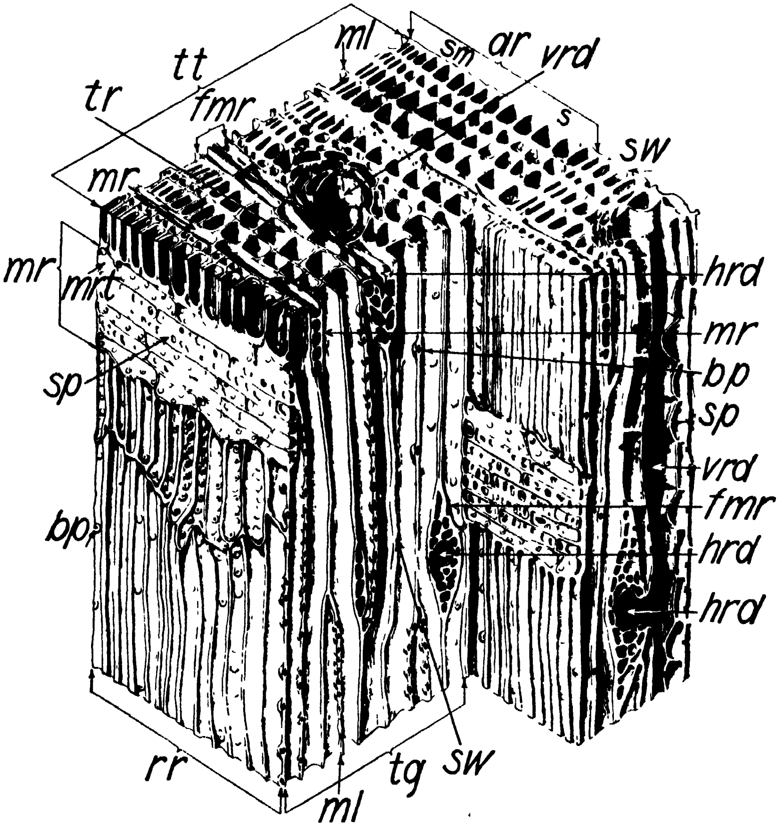

FIG. 59. — Stereo-Diagram of a Typical Coniferous Wood: *tt*, transverse or cross-section; *rr*, radial section; *tg*, tangential section; *ar*, annual ring; *sm*, summer wood; *s*, spring wood; *ml*, intercellular layer; *sw*, secondary wall; *vrd*, vertical resin duct; *hrd*, horizontal resin duct; *mr*, ray; *bp*, bordered pits; *sp*, simple pits; *fmr*, fusiform ray containing a horizontal duct, *mrt*, ray tracheids; *tr*, ordinary or vertical tracheids. (From United States Forest Products Laboratory.)

specific gravity of solid wood substance is about 1.54, whereas that of oven-dry woods ranges from 0.25 to 0.30 in light woods to 0.60 to 0.72 in very heavy ones.

The woods of the conifers (Fig. 59), as previously indicated (Chapter II) are made up almost wholly of tracheids—cells, somewhat fibrous in character—which serve, for a period after their formation, as conductive as well as mechanical elements. Vessels are lacking in the conifers. Rays are rarely conspicuous, and xylem parenchyma is missing or sparse. In the firs and the soft pines there is little difference between spring and summer wood, while in hard pines the seasonal difference in size and thickening of tracheid is considerable. The make-up of gymnosperm wood is therefore simple and homogeneous as compared with the

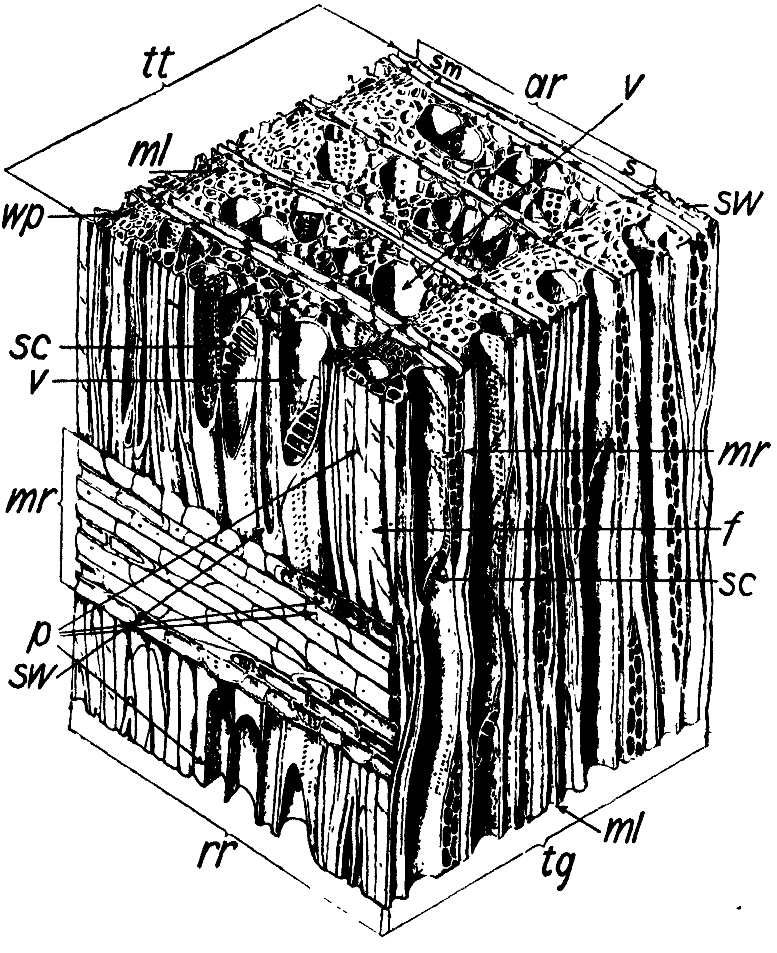

FIG. 60. — Stereo-Diagram of the Wood of a Dicotyledon: *tt*, transverse or cross-section; *rr*, radial section; *tg*, tangential section; *ar*, annual ring; *sm*, summer wood; *s*, spring wood, *ml*, intercellular layer; *sw*, secondary wall; *mr*, ray; *v*, vessel; *f*, wood fiber; *sc*, scalariform perforations in end-walls of vessels; *wp*, wood parenchyma; *p*, pits. (From United States Forest Products Laboratory.)

varied organizations to be found among the woody angiosperms. The tracheids, which are rather rectangular in cross-section, are laid down in very regular radial series; this arrangement and the general uniformity of the wood renders it easily split radially and with little difficulty tangentially.

The structure of the woods of dicotyledons (Fig. 60) is much more complex and much more varied. The dominant element is the wood fiber—an elongated cell of small diameter and relatively minute cavity—variable, however, in all of its characters; often approaching the tracheid as one extreme and parenchyma as another. Wood parenchyma is often abundant; the rays, of variable size, are aften conspicuous, and vessels are frequently large enough to be distinguished with the unaided eye. Some idea of the variety of structure in these woods may be gained from Fig. 61.

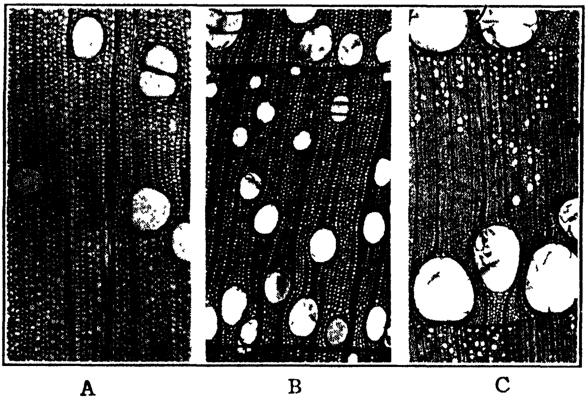

FIG. 61. — Variations in Hardwood Structure, as Seen in Cross-Section. *A*, Balsa (*Ochroma lagopus*), one of the lightest of woods (sp. g. 0.2), made up very largely of thin-walled wood parenchyma. It is a tropical wood, and annual demarcations are not evident. Balsa is in demand for airplane models, "cork legs," etc. *B*, the heavy wood of Black Walnut (***Juglans nigra***). The vessels are scattered; wood of this type is called diffuse-porous. *C*, the heavy wood of White Oak (*Quercus alba*) (sp. g. 0.7). The principal vessels are in the spring wood; timber of this type is called ring-porous. (Photomicrographs by United States Forest Products Laboratory.)

The terms SOFTWOOD and HARDWOOD, in common use in the lumber trade, merely designate a gymnosperm product in the first case and that of a dicotyledon in the second. It is true that the conifers, as a class, are probably softer than the other group, but the lindens, poplars, tulip wood, and some others classed as "hardwoods" are easily surpassed in actual hardness by the long-leaf pine, the larches, and several other "softwoods."

ANNUAL RINGS

In temperate-zone woods of either type, elements formed in the spring are usually large and thin-walled. As the season progresses, the cells laid down by the cambium tend to become smaller in diameter and thicker of wall. This sequence appears to be a reaction to the seasonal needs of the plant; the large vessels or tracheids of spring transmit abundant water-supply when the needs of the developing foliage is greatest. In gymnosperms, the thick-walled, fiber-like summer tracheids are chiefly concerned with mechanical support. In the more diversified structure of the angiosperm, wood fibers generally predominate in summer tissue; vessels and tracheids are likely to be few and small. The line of demarcation between the summer wood of one season and the tissues of the subsequent spring is usually plainly visible. As the annual wood-increment forms a sheath about the wood of the previous year, a woody stem presents a zonate appearance in cross-section, and a year's wood-growth is commonly termed an ANNUAL RING.

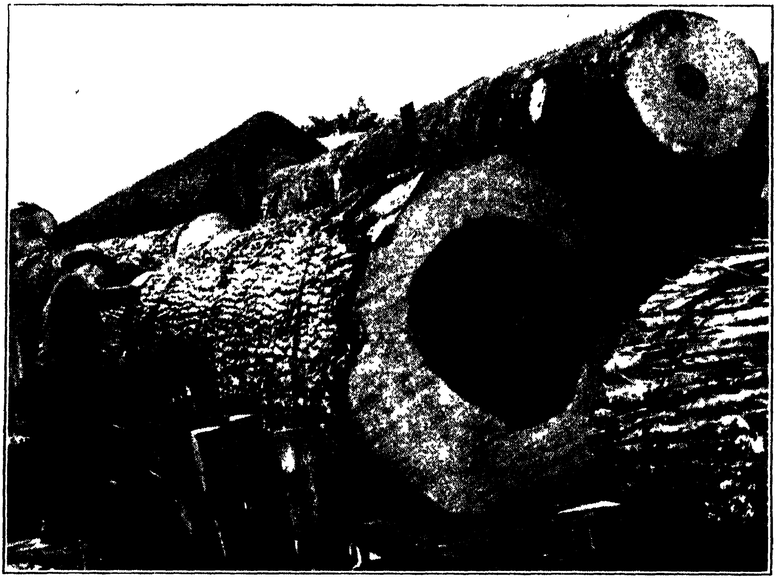

FIG. 62. — Logs of Red Gum (*Liquidambar styraciflua*). Note the pronounced differentiation between heartwood and sapwood characteristic of this species. (Photo from United States Forest Service.)

SAPWOOD AND HEARTWOOD

Young, actively functioning wood which usually forms a plainly marked zone within the cambium, is in most cases nearly colorless. Water-conduction and food storage seem to be confined to this region, which is termed the SAPWOOD. As time goes on, and more and more sapwood is formed by cambial division, the activities of the older cells gradually cease; the water-content of the inner region is reduced; and a variety of substances—gums, resins, tannins, coloring substances, etc.—infiltrate the cell walls and sometimes, as in ebony or mahogany, may occlude the cavities. In some woods, as in the white oaks, black walnut (Fig. 63), and black locust, TYLOSES—bladderlike enlargements of adjacent parenchyma cells—may penetrate the vessels and partially or completely close them. Food materials are withdrawn, to a great extent at least, from ray and parenchyma, and these living cells die, though in some instances their activities persist longer than those of the adjacent conductive tissues. In most woods, evidence of this cessation of physiological function is to be seen in color-changes of the central zone of the tree. These may be very slight, as in many of the pines, or extremely striking, as the red-brown of black cherry or apple, the rich brown of walnut, and the dead-black of ebony. The visibly differentiated central zone is now known as HEARTWOOD; it apparently functions only in the way of support. Usually it forms a rather regular central column. In some woods, however, marked eccentricities occur; the black wood of ebony and the faintly colored central portion of Douglas fir often contain enclosures and intrusions of so-called internal sapwood. These add striking variations, sometimes valuable and sometimes not, to the figure of lumber.

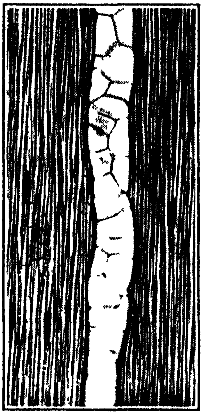

FIG. 63 — Tyloses in a Vessel of Black Walnut (*Juglans nigra*) Seen in Tangential Section. (Photomicrograph by United States Forest Products Laboratory.)

Sapwood varies from a few annual rings and a centimeter or less, as in black locust, to a hundred or more rings and two or more decimeters in many conifers. In hickories, maples, and many "white" hardwoods it furnishes the bulk of the log. In most of the woods used for furniture and finish, however, heartwood predominates. Apparently some of the substances developed in the formation of heartwood are somewhat antiseptic; heartwood, in general, is more resistant to rots and to insect attack; it possesses greater general durability than sapwood. This quality, however, varies widely in different woods. In actual strength, tests show little if any constant difference between heartwood and sapwood.

GRAIN

This term, like many others, has a confusing multiplicity of meanings. It may refer either to the TEXTURE or to the appearance or FIGURE of wood—all of which are, to be sure, correlated. The texture depends upon the cellular structure, and appearance is the resultant of cellular structure and exposed aspect of the wood.

As regards both texture and appearance, GRAIN may have several shades of meaning. As to texture, it may refer merely to direction of fiber; *straight-grained* woods, like those of most of the conifers, possess tracheids or fibers which run parallel and in quite regular radial series; such wood splits easily, especially in the radial direction; it may, however, be extremely resistant to breaking or bending stress. In *cross-grained* or *spiral-grained* woods (Fig. 64), the fibrous elements are intertwisted or irregularly arranged. Cross-grain is found about knots, crotches, etc., while spiral-grain is frequently found in species characterized in general by straight grain. While cross-grained and spiral-grained woods are sometimes of extreme resistance to splitting and breakage, the usual methods of sawing make the general direction of the fiber run diagonally in the lumber. The result is an inferior product. When small products of exceptional toughness—such as shingles, axe-helves, or airplane stock—are to be manufactured, a maximum of toughness is obtained by the

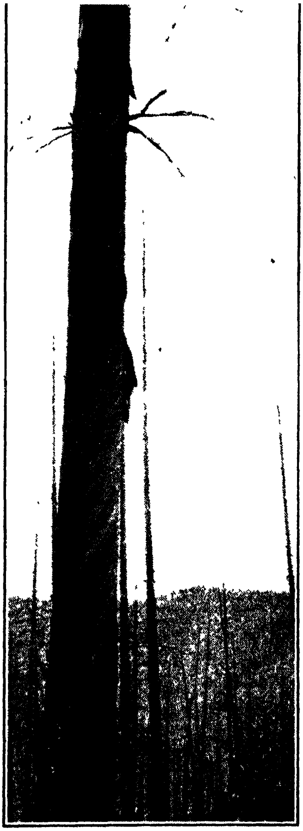

FIG. 64. — Tamarack (*Larix* sp.) St. Joe National Forest, Idaho. Note the spiral grain revealed by the peeling of bark following fire-killing. (Photo from United States Forest Service.)

selection of straight-grained timber and by splitting it rather than sawing it.

Wood which, like pearwood or ebony, consists chiefly of small thick-walled fibers, is described as fine-grained; coarse-grained woods, such as those of the oaks and elms, possess many vessels of large diameter. Woods of the latter type (unless the vessels are filled by tyloses) absorb liquids readily. They, with many of the conifers and others which because of the thinness of their cell walls or many pits have similar absorptive capacity, are classed in the painting trades as open-grained woods. With another shade of meaning, woods with wide and narrow annual rings (which are often though not invariably made up chiefly of large and small cells respectively) are termed coarse-grained in the first case and fine-grained in the second.

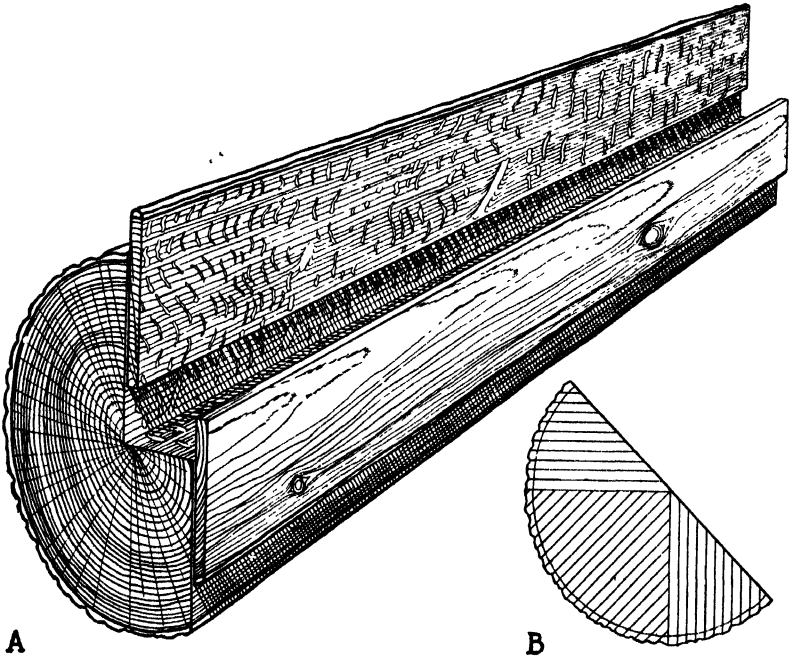

FIG. 65. — Methods of Sawing Lumber. *A*, a log with quarter-sawed board above and plain-sawed board below. *B*, various means of quarter-sawing lumber, which, for reasons of economy, is not cut in a geometrically radial manner. (From United States Forest Products Laboratory.)

Even-grained wood, like that of the white pines or tulip, is of homogeneous character; while such material as that of the hard pines, whose summer wood contrasts sharply with the spring wood in character and thickness of wall, is said to be of uneven grain. In some woods, such as the elms, certain tough elements twist partially loose in cutting or planing; such rough-grained woods are difficult to smooth satisfactorily; a fact which often interferes with their use for many purposes.

The appearance and visible marking, or figure, of wood varies very considerably according to the method of cutting (Fig. 65). The most striking figures are those of woods in which the annual rings are conspicuous. In *quarter-sawed* material (Fig. 66 and Fig. 68C) these rings form parallel lines; rays, when large enough to be visible, appear as streaks, cross-lines, or bands (termed silver grain when they are especially conspicuous). *Flat-grained* or *plain-sawed* lumber (Fig. 67*A* and Fig. 68*B*), produced by tangential sawing, affords great eccentricities of figure. A somewhat similar effect and even more striking pattern is attained in *rotary* veneer (Fig. 67*B*), which is peeled off in a thin layer from the surface of a rotating log.

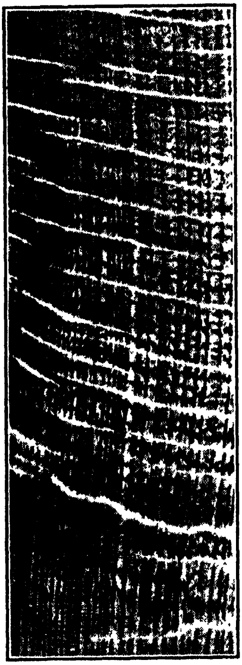

Fig. 66. — Quarter-Sawed Oak Veneer. (Courtesy of *The Furniture Manufacturer.*)

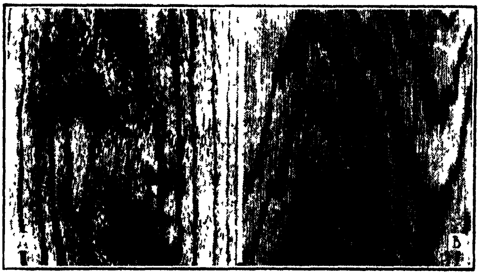

Fig. 67. — *A*, Plain-Sawed, and *B*, Rotary Cut, Oak Veneer. (Photo from United States Forest Products Laboratory.)

It will be seen that sawing "through and through" will result in a large proportion of flat-grained lumber, with the figure approaching the radial aspect as the center is neared. Because of economies of time and material in sawing, small logs and the cheaper grades of lumber are generally plain-sawed. Rift-sawed lumber, however, is less liable to checks, warping, and other forms

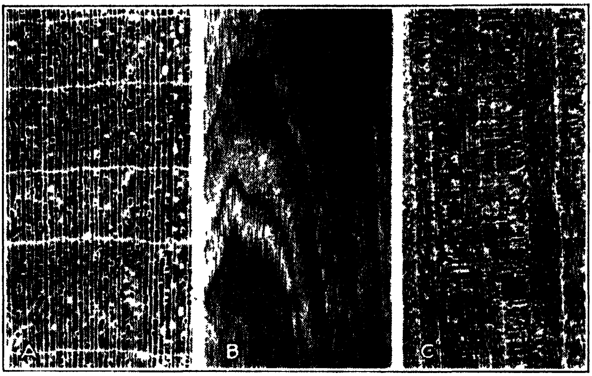

FIG. 68. — True Mahogany (*Swietenia mahogani*). *A*, end view (magnified); *B*, plain-sawed; and *C*, quarter-sawed surfaces. (Photo from United States Forest Products Laboratory.)

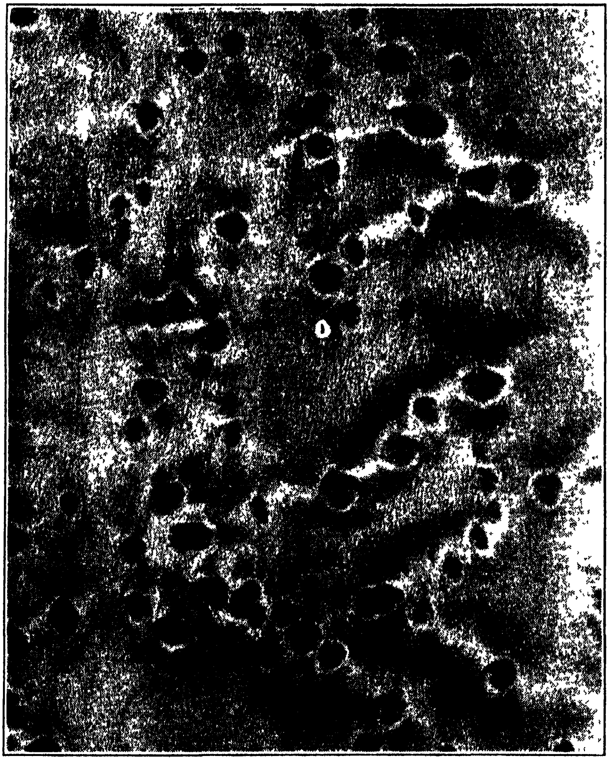

FIG. 69. — Bird's-Eye Maple. (Courtesy of *The Furniture Manufacturer*.)

of distortion in drying. For uses where surface-wear is considerable, as in flooring and shingles, it wears more evenly, and is less liable to warping and slivering which result from uneven absorption of moisture and the tendency of some woods to part at the junction of spring wood with the thick-walled elements of a previous season.

Peculiarities of figure, such as result from an interlocking of grain when the spirally twisted elements of one or several seasons' growth alternate in direction with those of an adjacent layer, burl, the bird's-eye formations in maple (Fig. 69), the twisted grain about crotches and knots, and various other irregularities, often add value to lumber. Cost is frequently enhanced by difficulties in working and smoothing these eccentric cell-formations. Sharp color-differences between sapwood and heartwood often result in striking peculiarities of pattern, particularly in rotary veneer.

The Seasoning of Wood

The water-content of freshly cut timber varies greatly, ranging from 30 per cent to over 200 per cent of the dry weight. This water is contained both in cell wall and cell cavity. "Green" lumber, when exposed to the atmosphere, immediately begins to lose water, and to shrink to some extent. Air-dry, or seasoned, lumber usually retains 10 to 15 per cent of moisture. The principal shrinkage is in the tangential aspect, which in oven dried material usually ranges from 5 to 10 per cent, as compared with 3 to 7 per cent in the radial direction and from 1/10 to 1/3 per cent in the longitudinal dimension. The actual shrinkage in the air-dried and kiln-dried material of commerce is somewhat less than this. The excess of tangential over radial shrinkage, and the radial-series pattern in which the cells are laid down by the cambium, results in some degree of radial cracking, or checking (Fig. 70), during seasoning. The actual size of the checks generally increases with the size of the lumber and the time of seasoning; it is a thing, of course, which it is desirable to minimize as far as possible.

As compared to freshly cut material, seasoned wood is lighter, stronger, less prone to warping, shrinkage, and checking in use, and less susceptible to fungus and insect attack. The shrinkage of green lumber renders it unsuitable for any kind of precise work, such as house finish, joinery, or furniture manufacture; and its large water-content interferes with painting, varnishing, gluing, and preservative treatment. It follows, therefore, that very little lumber is freighted or used in the green condition.

Wood for fuel use is also seasoned to reduce weight and to facilitate combustion.

Air-seasoning, which consists merely in exposure with a maximum of ventilation, was the original, and is the usual, process for the drying of lumber. Naturally the period required varies according to the dimensions and density of the wood, and according to atmospheric conditions. In dry weather, most light woods, in boards or small stock, season within a month or two; while large timbers and denser hardwoods require much longer.

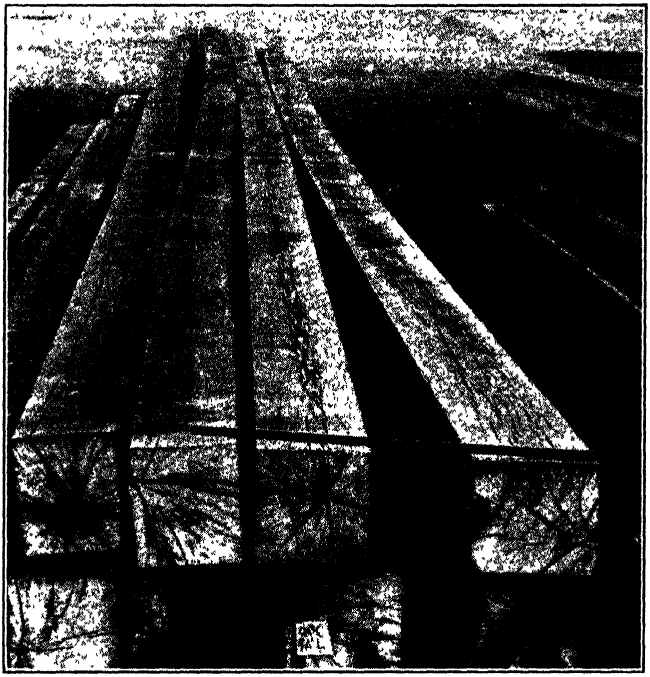

FIG. 70. — Oak Keel Stock, Checked and Warped in Seasoning, Philadelphia Navy Yard. (Photo from United States Forest Service.)

In recent years, much lumber, particularly shingles, finish, furniture stock, etc., has been seasoned by artificial heat, that is, kiln-dried. Kiln-drying (Fig. 71) may be accomplished in days rather than months in rapidly drying material, and in months rather than years in denser and larger stock. It minimizes or avoids air-seasoning injuries, such as checking, warping, and insect attack. The water-content of kiln-dried stock is less than that of air-dried lumber, usually ranging around 6 per cent.

Freight charges are therefore less; probability of shrinkage in use is reduced, and the product is better adapted to joinery and to gluing, painting, and preservative treatment. Prejudice is sometimes expressed against kiln-dried lumber, particularly as regards its strength; but apparently, if the process is correctly carried out, the product equals and is frequently superior to air-dried stock.

FIG. 71. — Load of Lumber Being Removed from a Kiln.
(Photo from United States Forest Service.)

The Durability of Wood

For many purposes for which wood is used, it is necessary only to consider strength, relative hardness, and dimension. Save for the effects of extrinsic agencies, wood changes little with the lapse of time. Among such agencies, fungi and insects are most prominent. Trees falling in a forest and dead wood under moist conditions disintegrate more or less rapidly under their attacks (Fig. 72). Inasmuch as decay is caused by living organisms, it can only take place within certain limits of temperature, in the presence of a considerable degree of moisture and of sufficient oxygen to support the respiration of causative agents.

FUNGUS DAMAGE

The optimum temperature for wood-rotting fungi is usually between 25° C and 30° C. One of the principal dry rot fungi, *Merulius lacrymans,* thrives best at a lower temperature, about 15° C. As these organisms are decidedly aerobic, they do not thrive in water, in saturated wood, or in the depths of water-logged or heavy soil. Decay in poles and pilings takes place most rapidly near the ground-line in posts and just above the water-line in pilings. A moisture content of 20 per cent or somewhat more favors rapid decay, especially under favorable temperature conditions, as in factories whose processes necessitate a warm, humid atmosphere. As well-seasoned wood usually contains not over 12–15 per cent of moisture, it is virtually immune to decay if protected against dampness. Woods also vary considerably in resistance when exposed to fungus attack. Heartwood, as has been noted previously, is generally more resistant than sapwood.

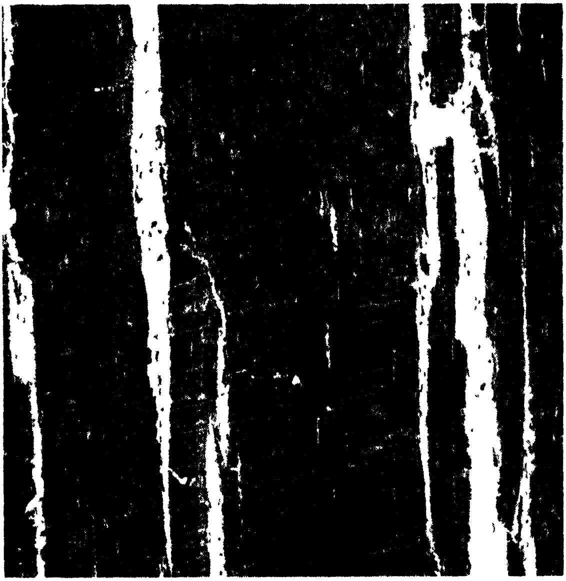

Fig. 72. — A Brown "Cubical Rot" of Hemlock, Caused by *Fomes pinicola*, a Bracket Fungus. White mats of fungus growth appear in the cracks. (Courtesy of Bureau of Plant Industry.)

In most buildings only the ground-timbers and shingles are seriously menaced. The endurance of these may be lengthened indefinitely by choice of resistant material, by preservative treatment, and by prevention of direct contact with the ground or other constant sources of moisture. Among the most durable timbers are the cedars, cypress, redwood, and chestnut. The spruces, firs, hickories, and maples are so little resistant to decay as to be useless as ground timbers. It will be seen that the strength and weight of different species have nothing to do with rot-resistance, which appears to be correlated wholly with the infiltration of antiseptic substances during the period of transition from sapwood to heartwood.

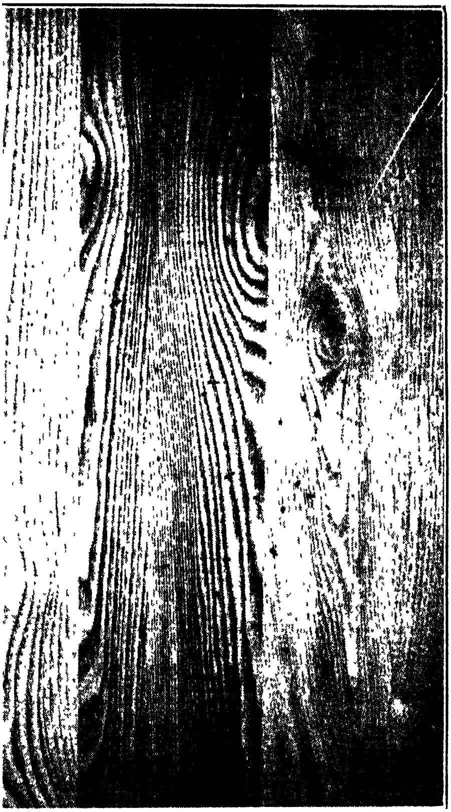

FIG. 73. — Worm-Eaten Chestnut, Cut from Dead (Usually Blight-Killed) Trees and Used for Veneer Cores. (Courtesy of *The Furniture Manufacturer.*)

INSECT DAMAGE

A considerable number of the grubs or larvæ (incorrectly termed "worms") of various species of Coleoptera (Beetles) and of Lepidoptera (Moths and Butterflies) as well as various other insects, feed upon wood. Some attack standing timber, but the chief damage is caused by those which infest the wood after it is cut or dead (Fig. 73). Many of these hatch from eggs deposited in the inner bark and later tunnel and ruin the sapwood (Fig. 74). These, in general, do not attack the heartwood, and they do not enter timber from which the bark has been removed. Others, such as the larvæ of the powder-post beetle, riddle the sapwood of several species of seasoned hardwood; and since, in their feeding, they shun the light, they may quite ruin timbers or the handles of tools, etc., with little outward sign of their presence. Termites, incorrectly known as "white ants," tunnel in ground timbers; they may also completely destroy the inner

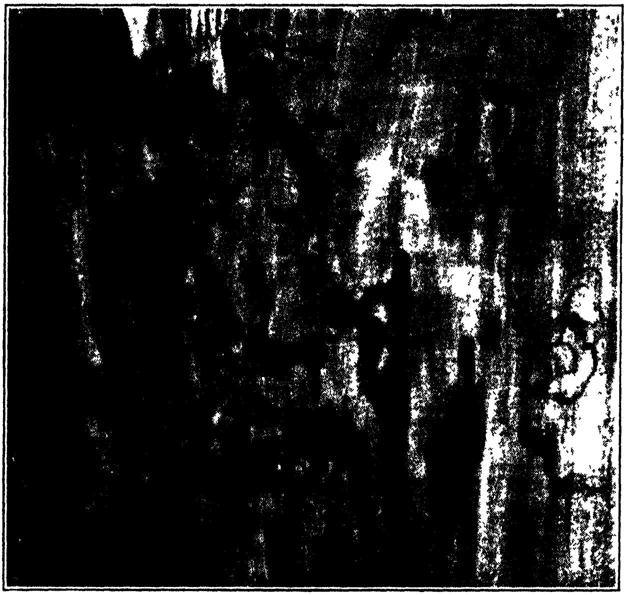

FIG. 74. — Larvæ of Boring Insects within Wood, as Revealed by the X-ray. Such insects rarely attack living wood, but soon appear in injured or dead tissue if moisture conditions permit. They introduce the spores of fungi, and decay soon follows. (Courtesy of Research Laboratories, Eastman Kodak Co.)

structure while leaving the outer surface untouched. In the tropics they cause incalculable damage to buildings and other materials made of wood or containing cellulose, and they are serious pests in some of the warmer regions of the United States. Some species of true ants also attack wood, but these are of minor economic significance.

The conditions of temperature, moisture, etc., which favor the development of fungi in wood are also, in general, favorable to insect attack; and the tunnelling and moving about of insects promotes the spread of fungi. Disintegration of dead wood in forests commonly results from combined insect and fungus infestation, and the same is often true of damage to stacked lumber or buildings. Some forms of termites, in particular, promote the spread of "dry rot."

MARINE BORERS

Pilings, hulls of ships, and other wooden materials submerged in salt water are often damaged by tunnelling mollusks and crustaceans, which from their immense numbers and the comparative rapidity of their progress are most serious menaces to marine construction. Apparently they do not feed upon the substance of the wood, but merely seek refuge within it.

FIRE HAZARD IN WOODEN CONSTRUCTION

The most obvious disadvantage of wood as a building material is its inflammable nature. If no other considerations were involved, this would prevent wooden construction of "skyscrapers," factories, and other buildings of large size or great height. Because the use of wood in framework, partitioning, floors, etc., always involves a certain degree of risk, it is not generally realized that the use of heavy timbers rather than unprotected steel supports in buildings of inflammable character may reduce damage hazard. A steel column (Fig. 75, p. 88) or girder becomes rapidly plastic under fire-heat and may collapse under a weight which it ordinarily supports with sufficient margin of safety. Although a wooden beam burns, fire penetrates it slowly and collapse is thus retarded. There are, of course, many ways of reducing fire-hazard in wooden or semi-wooden buildings by special methods of construction and by careful insulation of chimneys, heating and wiring systems, etc. The treatment of shingles and other exposed wood by fire-retardant chemicals is of some value. The great cause of fire, in prairie and forest, in building or ship, is not the inflammability of material but human carelessness.

PRESERVATIVE TREATMENT OF WOOD

Paint, varnish, enamels, etc., are usually applied to wood primarily to gratify the æsthetic sense, but they also aid in preserving its structure. The cellular nature of wood permits a certain degree of penetration by these substances, and the superficial film is consequently more firmly affixed. The coating is less fully waterproof than is commonly supposed, but it does considerably retard the absorption of moisture from rain and dew, and thus prevents warping, checking, and fungus and insect damage which otherwise would be incident to the alternate soakings and dryings to which unprotected wood is subject.

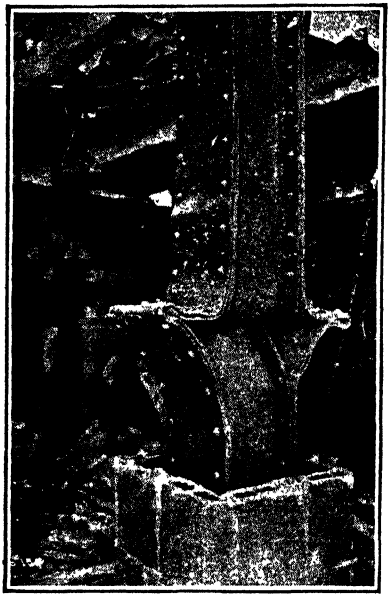

FIG. 75. — A Steel Column Softened by Heat. It crumpled under its load during fire, causing much damage. (From Koehler, *Properties and Uses of Wood*, McGraw-Hill Book Company, Inc.)

The expression "preservation of wood," however, usually refers to treatment or impregnation with creosote and various other chemicals for the definite purpose of protection against fungi, insects, and marine borers. Such treatment has demonstrated its value as concerns ties, posts, poles, pilings, shingles, and structural timbers which by their position are subject to such attack. Preservative treatment is destined to increase as its success becomes generally known and timber becomes scarcer and higher in price.

". . . The life of wood subjected to decay can be more than doubled on the average by properly treating it with preservatives. If all of the 9 billion or more board feet of timber which decay each year were properly treated, an annual saving of about 5 billion board feet could be effected. Nor is this all. Woods which heretofore were considered inferior—such as red oak, sap pine, cottonwood, box elder, white fir, and other non-durable kinds—could be used more extensively for ties, posts, and other timbers in places where decay of untreated wood may take place. Thus more of the desirable woods—such as white oak, locust, cypress, and redwood—would be left for higher class work or for uses for which preservative treatment is impracticable." [1]

Coal-tar creosote is the principal preservative used for ties, posts, piles, etc., which are to be used in soil or under water, where a soluble preservative would be leached out. For above-ground use, its oily character and dark color interfere with painting. For shingles, silos, etc., a considerable variety of colored creosote stains are available. Among water-soluble substances, zinc chloride is very effective in preventing decay.

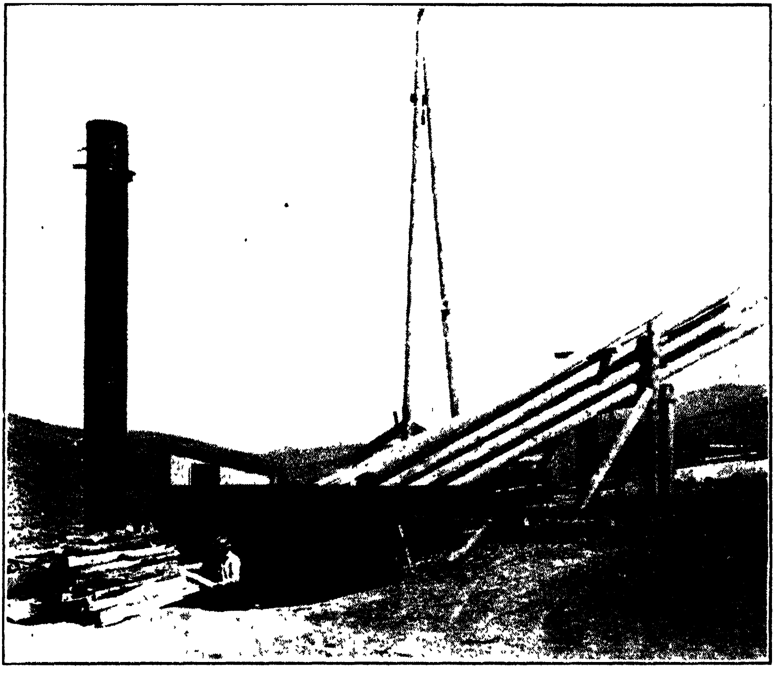

FIG. 76. — Preservative Treatment of the Bases of Lodgepole Pine Poles, Wasatch National Forest, Utah. (Photo from United States Forest Service.)

Preservatives may be applied by brushing, spraying, dipping (Fig. 76), or, when extreme penetration is desired, by various heating and vacuum-pressure methods. The soft pines and many of the lighter hardwoods absorb chemicals easily; heartwoods in general, especially those whose vessels contain tyloses, are penetrated with greater difficulty.

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[1] Arthur Koehler, *The Properties and Uses of Wood*, McGraw-Hill Book Co. (1924), p. 239.

"Fireproofing" of shingles, etc., specially subject to hazard is attempted by using paints with a high proportion of non-combustible matter and by impregnation with chemicals which, on heating, give off non-inflammable gases. Among the substances used are several ammonium compounds, borax, and zinc borate. Such processing retards combustion, often to a notable degree. Upon exposure to flame, treated wood chars, but does not blaze. A treated roof, for example, is long resistant to flying sparks, shingles, etc., from a nearby conflagration.

The Fastening of Wood

Almost any wooden construction implies the use of nails, screws, bolts, glue, etc., all of which owe much of their fastening value to the cellular nature of wood. In the softer woods, particularly, the displacements incident to the driving of nails and screws is readily taken up at the expense of the large cell cavities, with little distortion or danger of splitting. The holding power of a nail depends largely on the elasticity of displaced wood, which is considerable and which gives rise to frictional resistance when the nail is withdrawn. A nail or screw driven into the lateral aspect of wood (Fig. 77) holds much more strongly than one driven into the "end grain." A screw cuts for itself a spiral pathway, and is held both by friction and by the breakage-resistance of the more or less uninjured fibers in the spiral. As might be expected, the harder and more resistant woods are difficult to fasten and more prone to split; but, once secured, they have considerably greater nail-holding power than soft woods.

Glues are viscous liquids which adhere to most dry and non-greasy surfaces; when dried they form tough and tenacious films. When applied, they, like paints, penetrate the cells somewhat, and the surface film is thus anchored. The use of glue with pressure-friction, as in the tight-fitting rounds of chairs, and its application with mechanical pressure in the gluing of veneers, etc., increases its penetration. A good glue-joint in a soft and weak wood may be more resistant to strain than the surrounding wood itself. Failure of glue-joints in dry climates may be due partially to the shrinkage of the wood under such conditions, and in part to the fact that "dry" glue increases in brittleness as its moisture content decreases.

Matching, mortising, dovetailing, etc. (Fig. 78), include various methods of joining wood by means of the shapes into which it is cut. Such joints, in furniture, etc., are often glued; matched flooring, wainscoting, and the like, may be invisibly nailed.

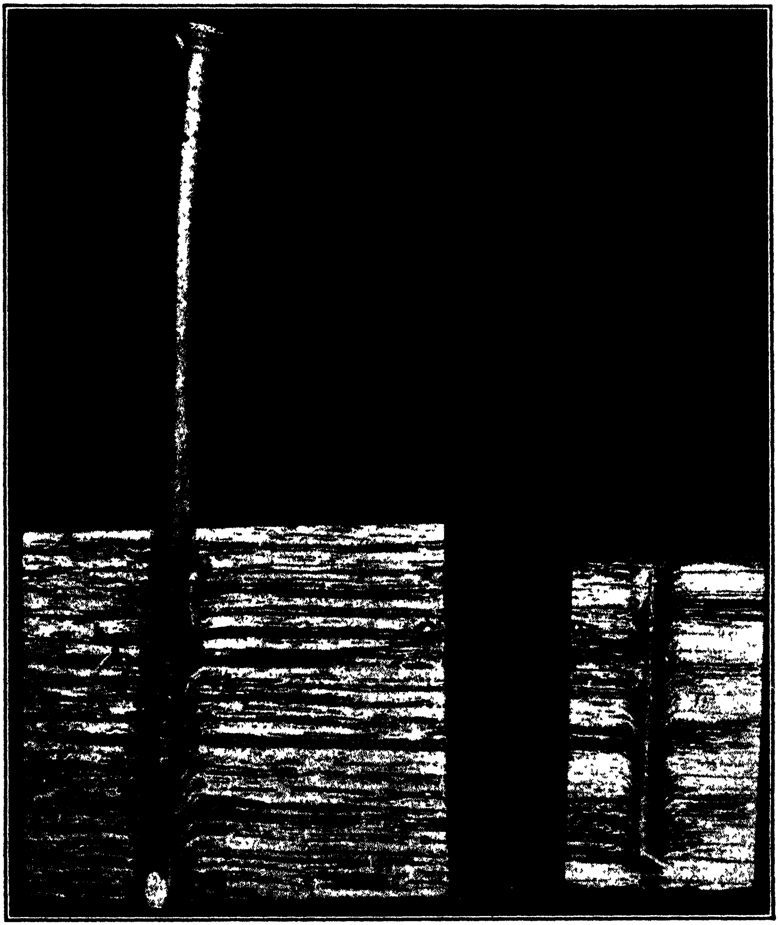

FIG. 77. — Displacement of Oak Wood by Nails. (Photo from United States Forest Products Laboratory.)

Measurement of Timber, Lumber, and Wood

Timber and lumber is generally measured, or scaled, by BOARD MEASURE. The unit of measurement, the BOARD FOOT, is reckoned as one foot square and one inch thick. The usual unit of sale is 1,000 board feet (abbreviated M.). As applied to standing timber and logs, scaling is designed to indicate not the actual volume but the practically obtainable lumber content. This, naturally, varies somewhat in accordance with the size of the log, its taper, the dimensions of the lumber to be sawed, and the method of sawing. A number of formulas have been devised for computing the board measure of timber, some of which are legal in some States and some in others.

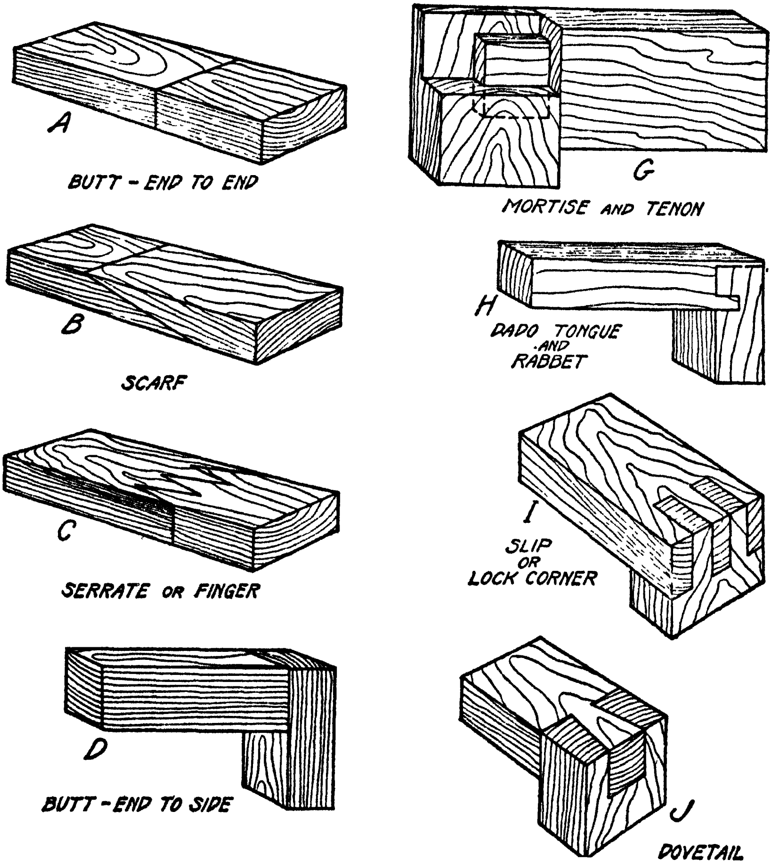

FIG. 78. — Types of Joint-Construction in Wood. *G, H, I,* and *J,* properly fitted and glued, make very strong corners. Such a joint as *A* is rarely used save when reinforced by another unjointed layer above or below. (From United States Department Agriculture Bulletin 1500.)

The actual width and thickness of sawed stock are likely to be a fraction of an inch scant—to compensate, presumably, for waste in sawing. Instead of being an inch in thickness, most boards are seven-eighths inch in the rough and three-fourths inch planed. Stock between three-sixteenths inch and one inch is reckoned as an inch thick. Veneer and stock under three-sixteenths inch are sold by surface measure.

Rough products such as mine timbers and poles are commonly sold by the linear foot under specifications governing piece-length and diameter. Ties, posts, and various miscellaneous products are sold by the piece.

The usual unit for fuel, pulpwood, and some other small stock is the CORD, which is reckoned as a stack of four-foot wood four feet high and eight feet long.

Cubic measure is not often used in the timber trade of the United States, but pulpwood, excelsior stock, veneer stock, pencil stock, and imported materials are sometimes sold by it.

CHAPTER IV

FOREST PRODUCTS: USES, DISTRIBUTION, AND KINDS OF WOOD

1. THE USES OF WOOD

So numerous are the applications of wood that merely to catalogue them would require a lengthy chapter. Only those of special importance can be mentioned in this volume; and the present chapter deals chiefly with constructional and allied uses, with fuel, and with various by-products of wood industries. Uses which depend primarily upon the cellulose content of wood, such as the making of paper from wood and the manufacture of textiles, are discussed in subsequent chapters.

With the exception of the coniferous products of Canada, which include important lumber products as well as pulp-wood and newsprint, and of mahogany, rosewood, and other exotic materials used in furniture, finish, and specialties, the United States supplies practically all its own timber and lumber.

Timber Products

Timber products may be grouped into several classes in accordance with their state of manufacture. The most obvious of these are: ROUGH OR HEWED PRODUCTS, used primarily for constructive purposes; PRIMARY MILLED PRODUCTS (chiefly lumber), used for constructional or other purposes with little or no further process of manufacture, and PRODUCTS MANUFACTURED from lumber; also FUEL and DISTILLATES. Various by-products which are in large part derived from waste, and the cellulose products, etc., may be discussed under other headings. It will be observed that in these classifications there is a considerable amount of overlapping; a hewed tie, for example, might properly be included in the first class, while a sawed one is a primary milled product. Furniture, also, is constructed partially of lumber and partially of stock made from primary lumber by further manufacture.

ROUGH AND HEWED PRODUCTS

Chief among these are ties, mine timbers, fence-posts, poles, and piling.

Ties.—A tie must be resistant to decay in contact with the ground. The impact of the heavy trains used in present-day rapid transit demands also a hard and durable wood. The white oaks, which excel in rot-resistance and durability, furnish about one-third of the ties used in the United States. Chestnut, at one time the principal source of such supplies, has been practically exterminated by a fungus disease, the Chestnut Blight; also, it is scarcely durable enough for heavy traffic. Red oaks, hard pines, and Douglas fir are other important sources of ties.

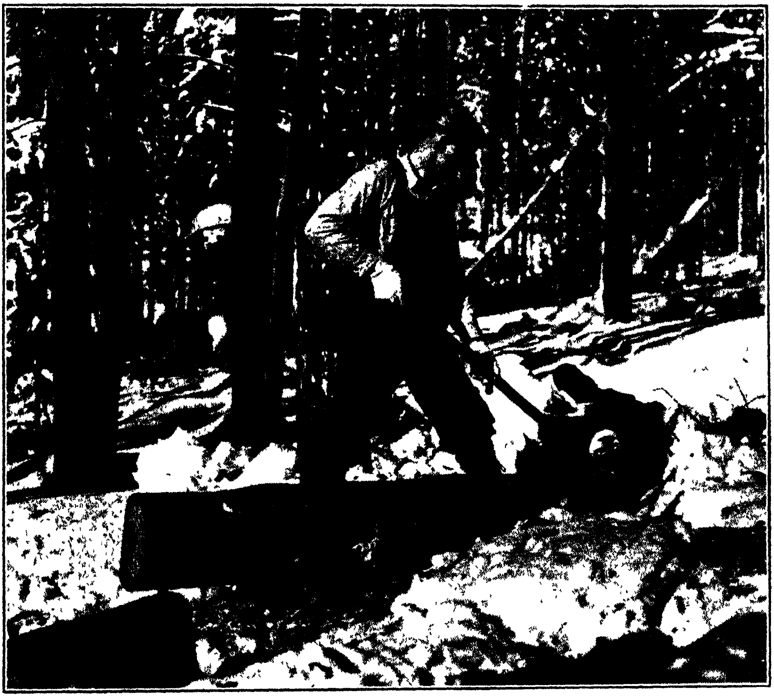

Fig. 79. — Spudding the Bark from a Hewn Tie, Targhee National Forest, Utah. All National Forests are managed on the principle of conservation, the aim being to remove lumber, ties, and other forest products from time to time without unnecessary destruction of surrounding timber. (Photo from United States Forest Service.)

When cut from timber of the proper size, railway ties require little preparation save peeling (Fig. 79), cutting to length, and flattening on two faces. The majority (85–90 per cent) of ties used in this country are hewed. Those cut from large timber and some others are sawed. Sawed ties, being somewhat roughened by the saw, have been supposed to absorb water more rapidly than the smoother hewed product, and therefore to be more subject to decay. Comparative tests indicate that this belief has little basis in fact.

In recent years a rapidly increasing proportion of ties have been treated with preservatives, as shown by the following table:

TABLE I

NUMBER OF TIES USED ANNUALLY IN THE UNITED STATES AND THE PERCENTAGE WHICH RECEIVED PRESERVATIVE TREATMENT.[1]

Year	*Ties used*	*Per cent treated*
1890	64,168,200	1.01
1900	83,429,400	3.36
1910	117,141,300	26.08
1920	137,100,000	37.81

[1] Adapted from Report of Proceedings of Meeting of American Wood Preservers' Association (1921), as cited in Koehler, *The Properties and Uses of Wood* (McGraw-Hill, New York, 1924), p. 286.

Mine Timbers.—These are usually small logs, rough or peeled, used to reinforce shafts and gangways in mines where the underground formations are likely to cave in. Some squared timber is also used for this purpose, choice being governed largely by cost and local availability. Decay-resistance in the presence of warmth and moisture are the chief requisites of mine timbers.

Poles, Posts, Masts, and Spars.—The chief use of poles is for the support of various forms of electric wiring. Durability underground, straightness, lightness, little taper, and a surface which will permit the ready use of climbing irons without the fraying out of dangerous splinters are among the requisites for poles. Coniferous trees grown in dense stands furnish the chief supplies of poles. Northern white cedar dominates; western red cedar and some pines are also of importance. Chestnut, once a principal Eastern source, is now unimportant. Preservative treatment of at least the underground portions of poles is now almost universal.

A limited amount of high-grade material is used for flagpoles, ship-masts, and spars. The demand for the latter, which was great in the days of sailing vessels, is now insignificant. White pine (Fig. 80), Norway pine, and Douglas fir excel in straightness, lightness, scant taper, and resilient strength—the qualities demanded in masts and spars.

A great variety of woods are used for fence-posts, the best being derived from the cedars. Durability and relative cheapness are the qualities sought.

Pilings. — These are straight timbers, usually peeled and in the round, which are driven beneath the water in the construction of wharves, docks, bridges, etc. Marine borers of several sorts are the chief sources of damage to pilings used in salt water; their ravages may be reduced to some extent by preservative treatment.

PRIMARY MILLED PRODUCTS

Coniferous woods furnish the basic building materials. As compared with hardwoods, they have several advantages:

They are the most abundant of North American timber trees whereas the hardwoods are chiefly localized in the East. Their wide distribution makes for economy in lumbering and transportation.

The great size of many of them (particularly of such important species as the redwoods, Douglas fir, northern red cedar, etc.), their excurrent growth, and their usual density of stand make for long straight boles with few and small

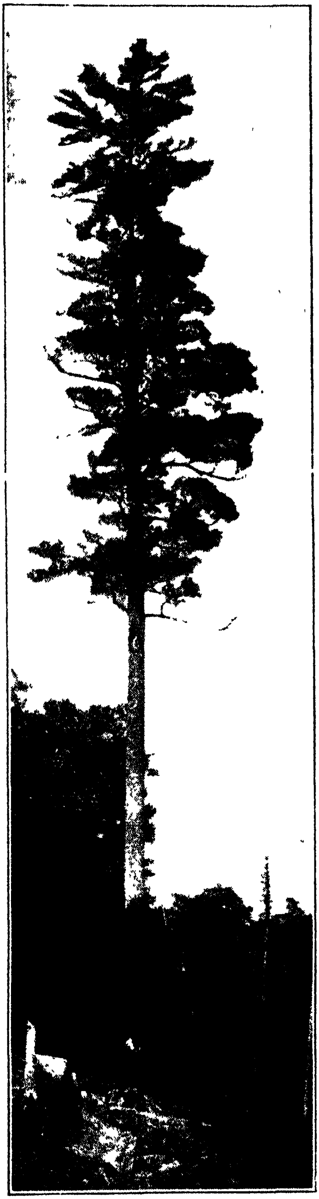

FIG. 80. — White Pine (*Pinus Strobus*). In American colonial history giant white pines, reaching 250 feet in height, were reserved for the use of the Royal Navy. Pines of such size no longer exist; something of the dimensions of this one can be judged by comparison with the figure of the man at its base. (Photo from United States Forest Service.)

knots; whereas the hardwoods with few exceptions are of deliquescent type, tending to form short trunks with large and irregularly disposed branches.

Coniferous wood is, in general, straight-grained; soft enough to be easily worked, and strong enough for ordinary constructional purposes without excessive bulkiness. Because of its simple and homogeneous structure, it usually seasons with a minimum of checking, warping, and other damage. The actual hardness, specific gravity, strength, and resistance to decay varies widely in different species, and to some extent within the species in accordance with conditions of growth. In general, hardwoods are heavier and stronger per unit of volume.

With the exception of knots and pitchy places, which must be removed or specially treated, coniferous woods take paints, varnishes, etc. well; when used for outside work they are less prone than the hardwoods to warping and checking through absorption of moisture.

Some, as the hard pines, are sufficiently durable for flooring, although selected hardwoods, such as maple and oak, are preferable in spite of the fact that they are more expensive.

The thin-walled tracheid structure of gymnosperm wood readily permits nailing, etc., with a minimum of distortion and splitting.

Many, such as the hard pines, redwood, and Douglas fir, show attractive patterns when properly cut. In general, however, the hardwoods are preferred for transparent finishes.

Many of the more important species—including the principal pines and redwood—seed well, are readily replaced naturally or artificially, and grow rapidly.

Structural Timbers.—The principal species used are the southern yellow pines, Douglas fir, redwood, and cypress. Hardwoods are rarely used; among them the oaks predominate.

Lumber.—According to Koehler[2] about 40 per cent of the annual output of lumber and dimension timber is used without further process of manufacture. One fifth of this is exported; the rest is used for constructional purposes. The remaining 60 per cent is used by the woodworking industries.

The principal sources of lumber are those species enumerated above as furnishing structural timbers and also a considerable number of other conifers. In buildings, hardwoods are in general used only for finish, flooring, etc.

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[2] A. Koehler, *The Properties and Uses of Wood* (McGraw-Hill, 1924), pp. 288–289.

Lumber Specialties.—Of these, shingles and laths, veneers and plywood, are worthy of special mention.

Shingles should be durable; free from excessive warping, shrinkage, or swellage under alternation of wetting and drying; and unlikely to split when nailed or crack in use. Radially sawed shingles are preferred. Western red cedar is now the principal source (Fig. 81), and a considerable supply is drawn from stumps of trees previously logged for other purposes. Red cedar shingles are almost invariably kiln-dried. Unsuitability of shingles for flat roofs, their relatively high cost, expense of laying, and fire hazard have resulted in extensive development of gravel, asphalt, metal, and other forms of roofing, and of fire-resisting shingles of mineral composition.

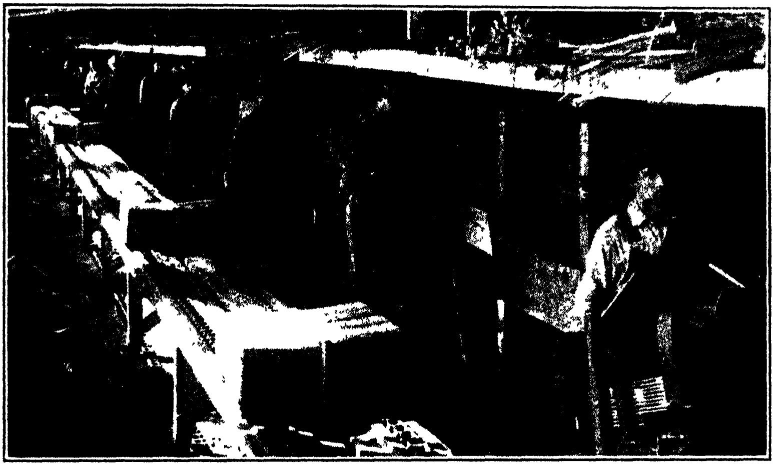


FIG. 81. — Packing Western Red Cedar Shingles in Washington. (Photo from United States Forest Service)

Lath are manufactured mostly from slabs, edgings, and other waste lumber. They should not shrink or warp in use, and they should not contain sufficient tannin or other substance to stain plaster. Spruce, hemlock, and other coniferous woods are chiefly used. Fireproof "metal lath" are now in extensive use both outdoors in stucco construction and indoors, and "plasterboards" of various mineral compositions are common for inside work.

Material ranging from paper-thinness to one-fourth inch or a trifle more in thickness is known as veneer. It may be manufactured by longitudinal SAWING or SLICING, or by ROTARY CUTTING in a special lathe.

In sawing veneer no special treatment of the wood is necessary. Sawing produces high-grade veneer, but the process is not adapted for the production of very thin veneer, and it entails some waste in sawdust. For slicing and for the making of rotary veneer the wood is thoroughly steamed or boiled till saturated and as plastic as its nature permits; cutting is thereby facilitated and the danger of splitting the thin product is reduced to a minimum. Sliced veneer is made in a machine which moves the block diagonally up and down against a heavy knife. Radial veneer, such as that of quartered oak and woods of uneven texture or eccentric grain, is usually cut in this way. Sliced veneer can be cut to a

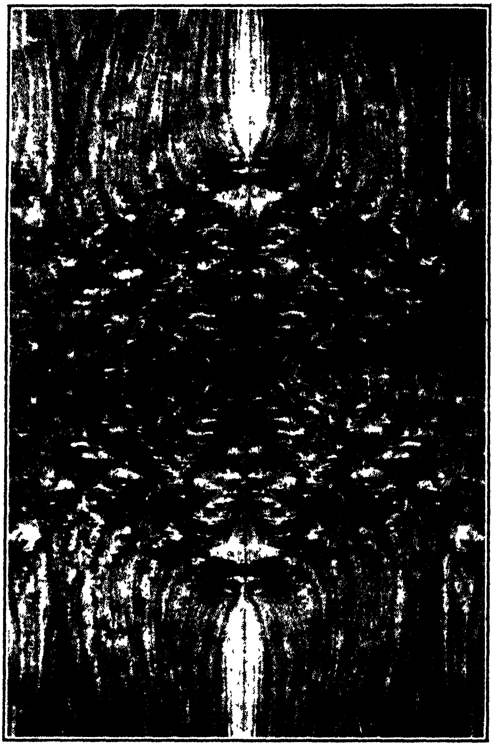


FIG 82. — Walnut Stumpwood Veneer. Symmetrical effect obtained by turning over two of four adjacent pieces. (Photo from United States Forest Products Laboratory.)

thinness of 1/120th inch or less, but its width is naturally limited to that of the bolt from which it is cut.

Rotary veneer is cut in a heavy lathe (Fig. 84), the bolt revolving with constant pressure against the knife. This peels off a continuous sheet which is carried from the machine much as a layer of wall-paper might be unrolled. Practically all the cheaper veneers, and many others, are made in this way. The peripheral cut produces a very flat-grained figure; this, in many woods, is an advantage.

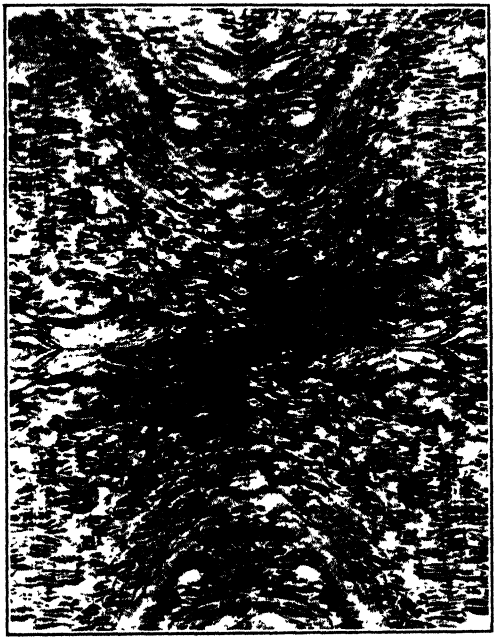


FIG. 83. — A Four-Piece Matched Walnut Veneer Panel. (Photo from United States Forest Products Laboratory.)

For furniture and the making of doors, panels (Fig. 85), etc., veneer is glued on a base, or core, of cheaper wood (Fig. 73). Veneer cores are often built up of small pieces which otherwise would be wasted. For many purposes a veneered article is preferable to one of solid hardwood, as it is much less subject to warping and checking under alternations of humidity and dryness.

Plywood, extensively used for panels, chair- and seat-bottoms, etc., is made by gluing an odd number—three or more—sheets of veneer with the grain of each piece at right angles to the next.

This construction combines a considerable flexibility with little liability to splitting.

Great quantities of light and cheap veneer are used in the making of orange-boxes, fruit-baskets, market-baskets, barrels, cases for radios, phonographs, and other bulky but light furniture, bottoms of drawers, and for innumerable other uses.

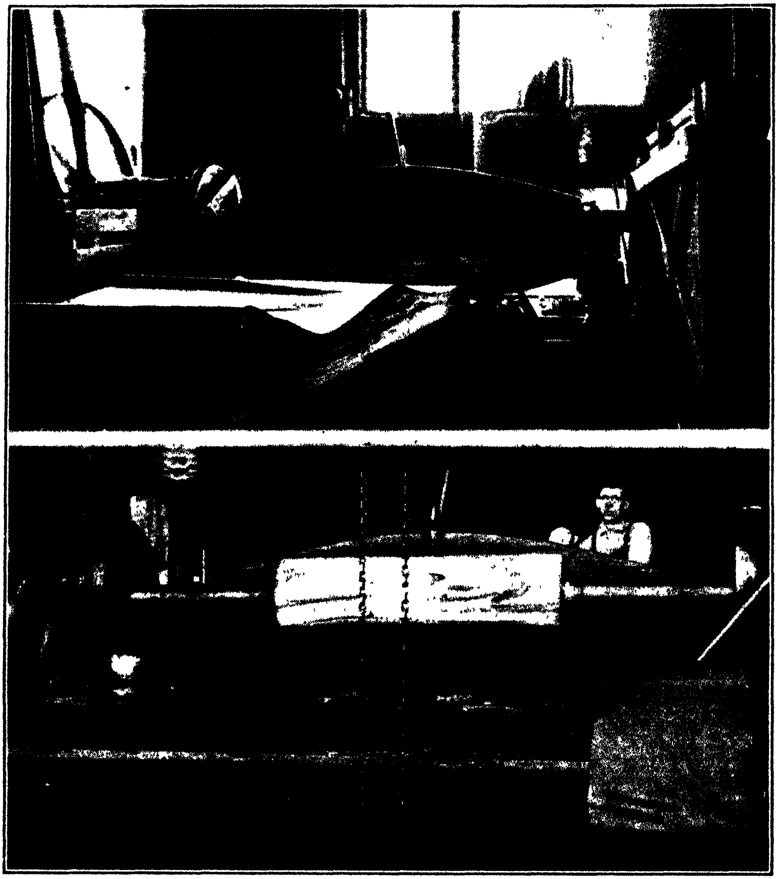
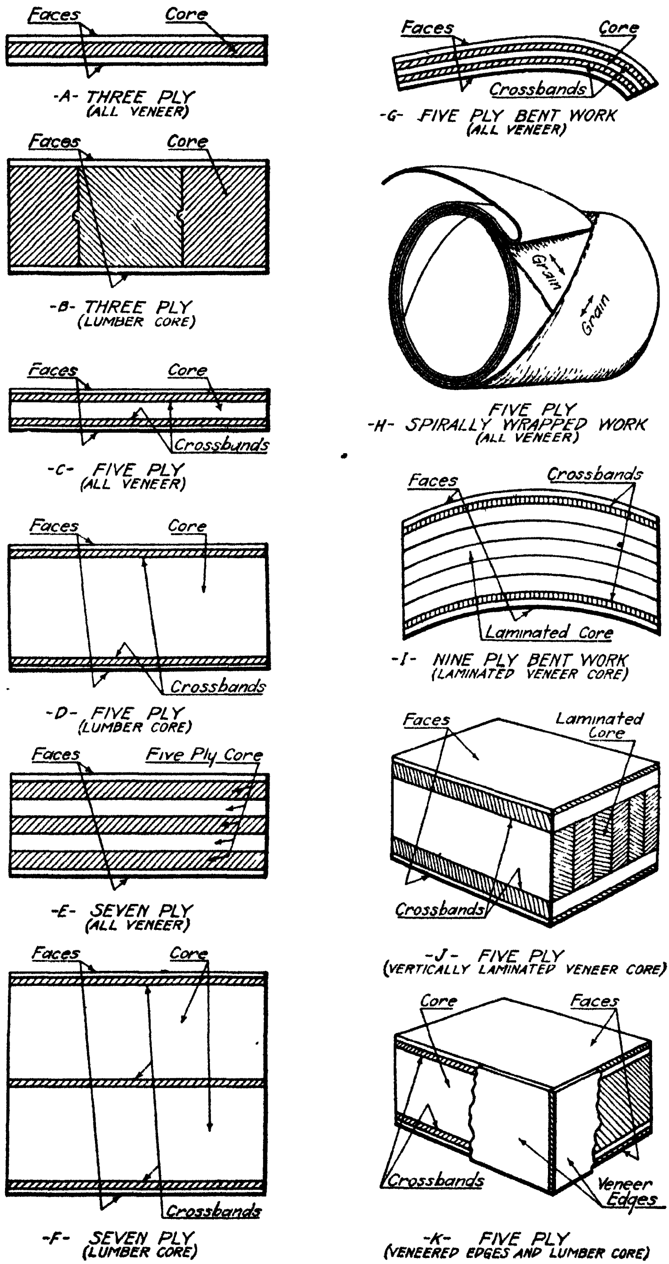


FIG. 84. — A Lathe Cutting Rotary Veneer. The machine is adjustable for different lengths. A bolt two feet in diameter and four feet long, cut into veneer one-twentieth inch thick, will produce nearly enough to cover 3,000 square feet. In the upper view, the front of the lathe is shown, with a pile of veneer-sheets in the foreground. Below is a rear view, with the bolt rotating against the knife. (Photo from United States Forest Products Laboratory.)

Excelsior.—This product is said to have been introduced as a cheap filling in mattresses, etc., and to have been named from



-A- THREE PLY (ALL VENEER)

-B- THREE PLY (LUMBER CORE)

-C- FIVE PLY (ALL VENEER)

-D- FIVE PLY (LUMBER CORE)

-E- SEVEN PLY (ALL VENEER)

-F- SEVEN PLY (LUMBER CORE)

-G- FIVE PLY BENT WORK (ALL VENEER)

-H- FIVE PLY SPIRALLY WRAPPED WORK (ALL VENEER)

-I- NINE PLY BENT WORK (LAMINATED VENEER CORE)

-J- FIVE PLY (VERTICALLY LAMINATED VENEER CORE)

-K- FIVE PLY (VENEERED EDGES AND LUMBER CORE)

FIG. 85. — Diagram Showing Types of Plywood and Veneered Construction. (From United States Forest Products Laboratory.)

Longfellow's famous poem. It is still employed for filling in upholstered furniture, but principally for packing glass, chinaware, and other easily broken articles. It is made by shredding wood bolts with rapidly moving knives and spurs or steel teeth (Fig. 86); the loosened shreds are pared off by a knife. Wood for excelsior use should be light, free from obnoxious odor, straight grained, and fairly tough. Basswood makes the best excelsior but is limited in supply. Larger quantities come from the cottonwoods, poplars, loblolly, and others of the softer yellow pines. About 200,000 cords of wood are used annually in excelsior; New York leads in number of plants and Wisconsin in output.

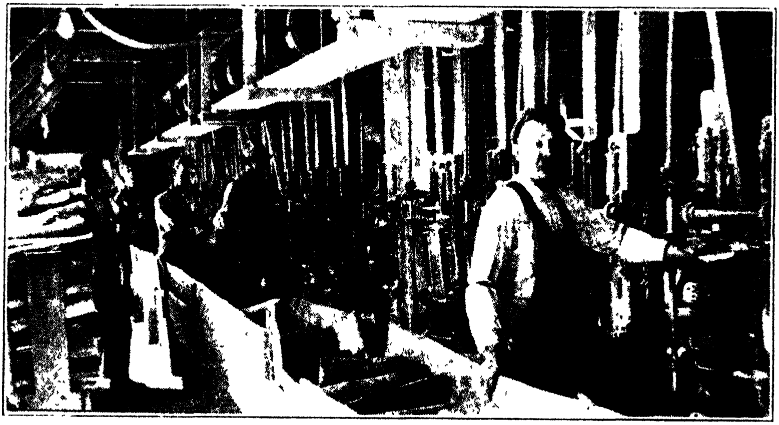


FIG. 86. — Manufacture of Excelsior. Poplar bolts, cut two feet long, are shredded on upright machines, each of which will cut about 500 pounds of excelsior in a ten-hour day. One operator handles six machines. Larger machines of horizontal type are also used. (Photo from United States Forest Service)

Manufactured Wooden Products

These are of endless diversity.

"About 24,500,000,000 board feet of all lumber cut, or slightly over 60 per cent, is remanufactured into wooden products. . . . Planing mills consume about 13,500,000,000 board feet of this in manufacture of sash, doors, blinds, moulding, flooring, casing, ceiling, partition, siding, and general millwork. . . . The manufacture of boxes and crates is next in demand on lumber . . ." [3]

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[3] A. Koehler, *The Properties and Uses of Wood* (McGraw-Hill Book Co.), p. 295. For a very extensive tabulation of quantities and kinds of wood used for various purposes, see U.S.D.A. Bull. 605; also Koehler, pp. 296–301.

Among other major or interesting categories taken from the tabulation cited in the foot-note, are car construction, furniture, vehicles and vehicle parts, miscellaneous woodenwares, agricultural implements, chairs and chair-stock, handles, musical instruments, tanks and silos, ship and boat building, fixtures, caskets and coffins, and refrigerators and kitchen cabinets, each one of which consumed over 137,000,000 board feet annually. Matches and toothpicks utilized 85,442,111 board feet, of which 73,059,611 was white pine for matches. That toothpicks should claim 4,775,000 feet of birch and maple annually is—considering the volume of the average toothpick—a dubious comment on American table etiquette.

COOPERAGE

Cooperage includes a vast variety of articles made of staves. The majority are small—barrels, kegs, pails, tubs, and the like—but tanks, silos, and even wooden pipe-lines hundreds of miles in length, used for conveying city water supplies, are of similar construction. The wooden materials used in ordinary cooperage are staves, heading, and hoops—all so well known as not to need description. These are usually "roughed out" at a mill and finished at the cooperage plant, often by first thoroughly soaking the bolts, slicing to shape, and then bending the saturated wood to the required form. Containers designed to hold liquids are classed as TIGHT COOPERAGE; those for other purposes are SLACK COOPERAGE. Demand for both types of cooperage has been markedly changed by modern methods of merchandising. Flour and apples, once almost wholly marketed in slack barrels, now travel almost wholly in the more readily portable paper sack, box, or wooden crate. "Tub butter" is almost a thing of the past, and lard and similar products are now more commonly sold in tin than in wood; the same may be said of molasses. Petroleum products, once sold very largely in barrels, are dispensed by tank car, pipe-line, and the corner "gas" station. The kerosene lamp has been replaced by the incandescent. The chief of all uses for tight cooperage was curtailed by prohibitory legislation. Repeal of the Eighteenth Amendment was the signal for sudden increase in production of keg- and barrel-stock, but, judging from the general present-day preference for small packages it may be doubted whether tight cooperage will ever regain its former importance in the merchandising of alcoholics.

Slack cooperage, in general, is made of soft and light wood. Tight cooperage is much more restrictive as to kind and quality.

The white oaks make the best tight barrels, the large vessels being, in heartwood, quite occluded by tyloses.

Tanks of various kinds and silos are frequently made of wooden staves and hooped with metal. Cypress, cedar, and redwood, being long resistant to decay, make excellent tanks; and a variety of softwoods are used for silos.

The use of stave pipe for aqueducts (Fig. 87), flumes, etc., is common in the Far West, where suitable lumber—such as redwood—is abundant and cheap and where water must be conveyed long distances for drinking, mining, or irrigation. A hydrostatic pressure sufficient to keep the wood saturated excludes the air which favors fungus development, and thus preserves the pipe almost indefinitely. The use of non-water-soluble preservatives may often be of advantage.

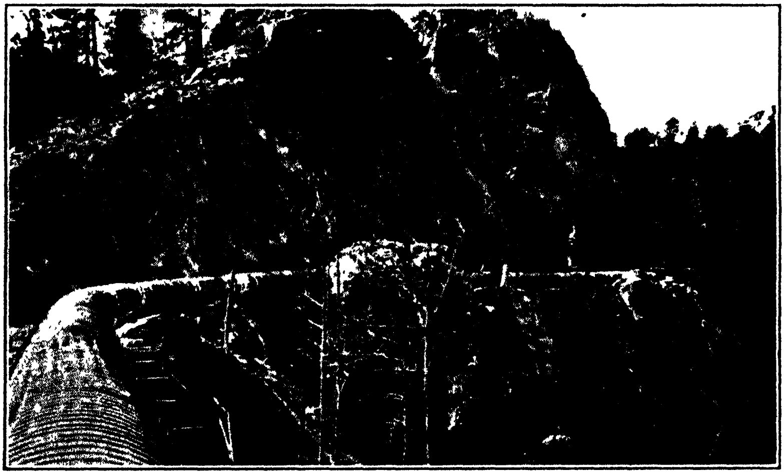

FIG. 87. — A Wooden-Stave Penstock in the Black Hills National Forest, South Dakota. (Photo from United States Forest Service.)

Wood pipe, in the West, is usually cheaper than metal; is less subject to injury from freezing, settling, or expansion; and may readily be repaired. In some localities, concrete pipe is being substituted.

BOXES, CRATES, ETC.

These containers are usually made of cheap soft wood or plywood. For heavy boxing and crating and for the packing of vegetables, fruit, etc., which demand a certain amount of aeration, there are no suitable substitutes for wood. For canned goods, soap, and a vast variety of groceries and similar products, even including materials packed in glass, pasteboard boxes have grown rapidly in favor in recent years. They are less bulky, lighter, more easily handled and disposed of, than wooden containers, and sufficiently strong for most packages of easily portable size.

FURNITURE

Most American furniture and the bulky parts of nearly all of it are made of American woods. For the showy portions, both native and foreign woods are employed. No "Pure Wood Law" has been enacted to guard quality and identity, and as a consequence the more valuable species, such as the mahoganies and walnuts, are imitated and substituted for on a scale that would be deemed rank fraud in almost any other merchandise. Showier portions of furniture are often made of or veneered with one of the more reputable walnuts or mahoganies, and those in less plain view of red gum or birch, carefully stained to match the rest.

The principal characteristics which recommend wood for furniture are its durability, its proportion of weight to bulk and strength, the readiness with which it may be shaped and worked, and the pleasing figures and finishes which may be obtained. Cost and the fact of long and habitual usage are also in favor of wood. For business purposes, particularly where reduction of fire hazard to records, etc., is a major consideration, steel is being increasingly used as a substitute. With the exception of a comparatively few articles, such as bedsteads, metal household furniture is not commonly used. The chilly "feel" of metal is probably a deterrent to its more common use.

Nearly all the furniture used in the United States is of domestic manufacture, and the industry is an important one. It is localized chiefly in the East and in important hardwood producing regions. With respect to value of product, the States have ranked as follows:[4] New York, Illinois, Michigan, Pennsylvania, Indiana, Wisconsin, Ohio, Massachusetts, North Carolina. At the time of the surveys cited, New York led in the number of men employed and North Carolina in the number of board feet of lumber consumed.

Exports as well as imports of furniture are small. The finished commodity is extremely bulky in relation to its weight; easily broken or marred in transit; is subject to extremely high freight rates and, in many countries, to high import duties—all factors which reduce its international movement.

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[4] Data from Tariff Information Surveys on the Articles in Paragraphs 175, 176 of the Tariff Act of 1913. D-4. U. S. Tariff Commission (Washington, 1921), p. 38.

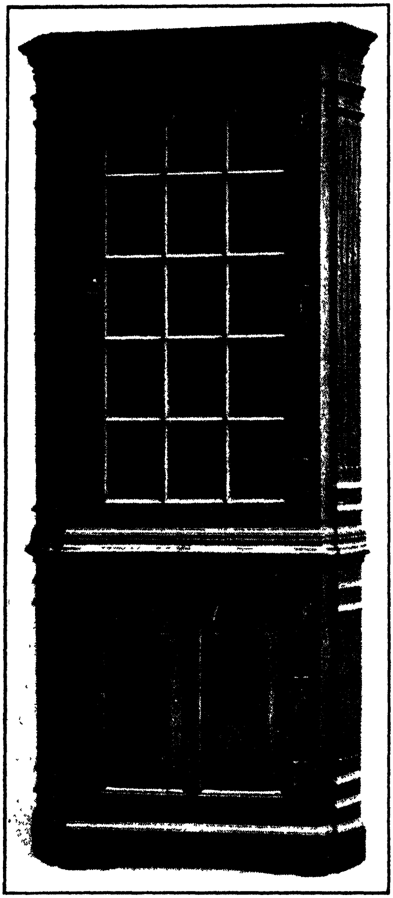

Fig. 88. — An American Walnut Cupboard, Made about 1745. (Courtesy of the Metropolitan Museum of Art, New York, N. Y.)

As to amounts of different kinds of woods used in the American furniture industry, a computation made some years ago by the United States Forest Service placed oak, maple, red gum, and birch in the order named. Oak, the great American furniture wood, holds its place because of its abundance, hardness, durability, appearance, and the readiness with which it takes various finishes. The rather glaring and once popular golden oak is now decidedly in disfavor for household use. "Mission furniture," in which oak reappeared in altered style and duller hue, and the somber shades of "Flemish oak" and "fumed oak" succeeded the shining varnish of the golden oak era and have themselves been replaced. "American walnut" (Fig. 88), which for some years past has been in great demand, accounts for the appearance of the once little used red gum in third place; birch, a valuable hardwood in its own right, is often finished and sold as mahogany or walnut. Maple, which deservedly ranks second in the chair industry as well as in total furniture use, is occasionally stained to imitate other and darker woods. Maple of peculiar figure, such as bird's eye (Fig. 69), curly maple, and burl, is in some demand for bedroom furnishings.

Wood as Fuel

Wood, the chief fuel of man until the present age, is still of great importance as a source of heat. The more popular fuels of American cities—coal, petroleum, and gas (both natural and artificial)—merely present inflammable components of vegetation of past geological time in concentrated or readily portable form. It is said that probably as great a volume of wood is still used for fuel as for all other purposes combined. The firewood of the present day, nevertheless, is in general to be looked upon only as a by-product of the lumbering and woodworking industries. Cordwood is obtained from the unmerchantable tops and branches of trees cut in lumbering, from open-land trees of no timber value, from culls of the timberland, and from farm woodlots and mountainsides whence desirable species have been removed and replaced by natural seeding with inferior quickly growing kinds. Vast quantities of slabs, edgings, and other wastes of sawing accumulate at mills. Since much "slash" and sawmill waste accumulates in places remote from large settlements, great quantities of potential fuel still rots on the ground or is burned to get rid of it or to avoid fire hazard. Because of its bulk and high freight rates, comparatively little wood is transported far for fuel.

It has been elsewhere stated that the chemical composition of wood varies little. Except for resin content, there is little variation in the heating qualities of equal weights of wood. Resin, being highly inflammable and low in oxygen, gives off about twice as much heat per unit of weight as air-dry wood. Therefore the southern pines and other resinous conifers may be more valuable sources of heat than their weight would indicate. This value is counterbalanced to some extent by their tendency to incomplete combustion with the evolution of unpleasant black smoke and soot.

Wood, with rare exceptions, is sold by the cord, and a cord of heavy wood, such as maple, oak, or hickory, is of considerably more heating value than a cord of lighter cedar or spruce. Hardwoods of the heavier sorts, when well seasoned, burn rather slowly and completely; they are, in general, preferred for heating purposes. Two pounds of seasoned wood are approximately equal to a pound of coal in heating value. A cord of wood yields, on the average, about 80 cubic feet of fuel and is equivalent to from one-half to one ton of coal according to the character of the wood.

Wastes and By-Products

Some idea of the magnitude of the waste-wood problem may be gained from Fig. 89, which attempts to show graphically the wastes and uses of American lumber. Apparently under the best modern lumbering conditions only about one fourth of the wood in the forest is actually used for purposes of construction, and, if account were taken of the wood in the roots, the proportion would be still less. Inasmuch as nearly all of this waste could theoretically be gathered and used for fuel or other purpose (as in practice it would be in most parts of Europe), it may be considered simply as the result of present conditions in a country of vast distances, irregularly and sparsely settled, and blessed with a still abundant supply of relatively cheap coal, gas, and other fuel. In remote regions, only about 15 to 20 per cent of standing hardwood can be profitably cut into lumber; the rest remains on the ground, theoretically a valuable replenishment of humus in the course of time, practically a serious fire-menace. In regions nearer settlements, a considerable proportion of tops and branches may be utilized as fuel, and much of the waste in mill and factories

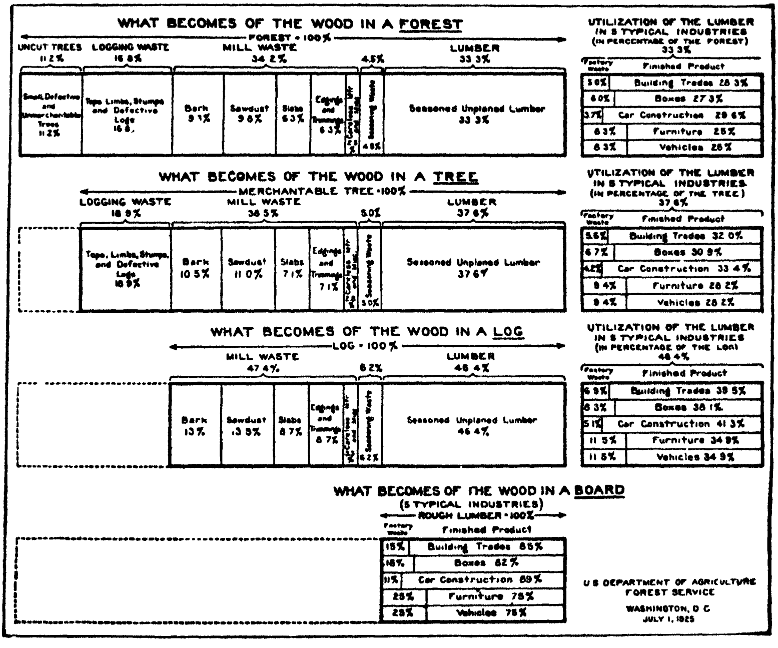

FIG. 89. — What Becomes of Wood. (Chart by United States Forest Service.)

is burned to heat the boilers or is locally disposed of. Other wastes might be used in distillation or in manufacture of pulp, paper, cellulose products, etc. Modern chemistry has proved that the economical farmer's dream of feeding his stock on sawdust may be an actuality; that it is not profitable at present is only because of the cost of processing the sawdust. Even bark, the most generally useless refuse of lumbering, can be used in the composition of various coarse pasteboards and composition products. In general, the problem of profitable utilization of timber wastes is, primarily, a problem in transportation.

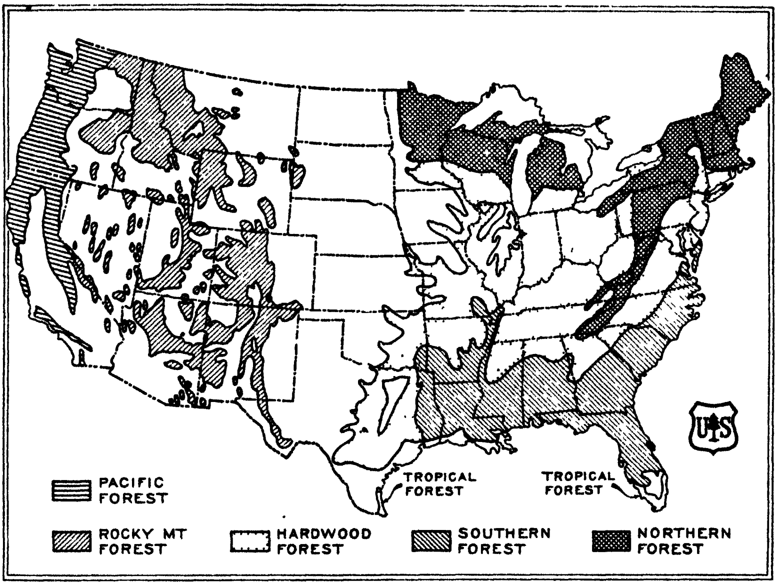

FIG. 90. — Forest Regions of the United States. (From United States Forest Service.)

2. DISTRIBUTION OF FOREST REGIONS OF THE UNITED STATES

The forest map (Fig. 90) shows the distribution of natural forest regions of the United States. Settlement, particularly in the East, has much modified the natural-forest condition of these areas (Fig. 91). Figure 92 indicates the lumber harvest of a single year from the principal forest States.

The Northern Forest

This area extends from New England westward nearly across Minnesota, with a southern finger following the Appalachian ridge. It blends at the north with a forested band of coniferous country covering southeastern Canada and swinging northward through Manitoba toward Alaska.

The dominant natural vegetation of the northern forest is coniferous. White pine is the most valuable species, though its former areas have been much depleted and blister rust and insects have interfered with reforestation. Other gymnosperms

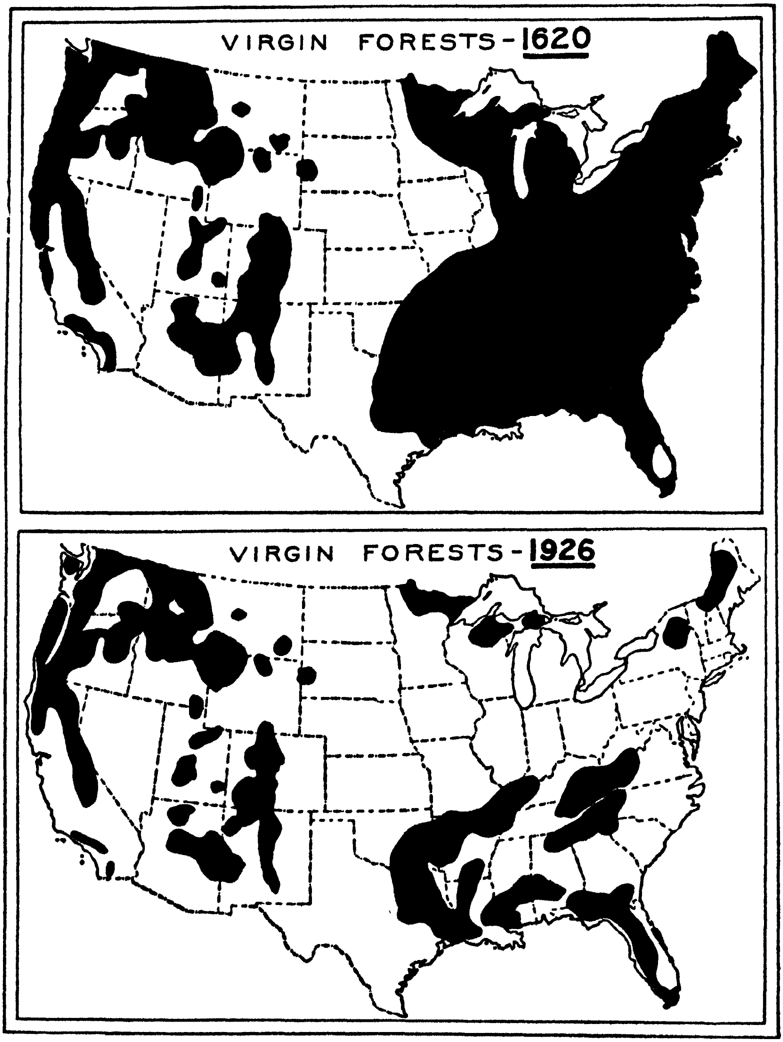

Fig. 91. — Past and Present Forest. (From United States Forest Service.)

include spruces—principal sources of wood-pulp—hemlock, balsam fir, and (northerly) white cedar. Numerous broad-leaf species mix with the softwoods, particularly on the less sandy

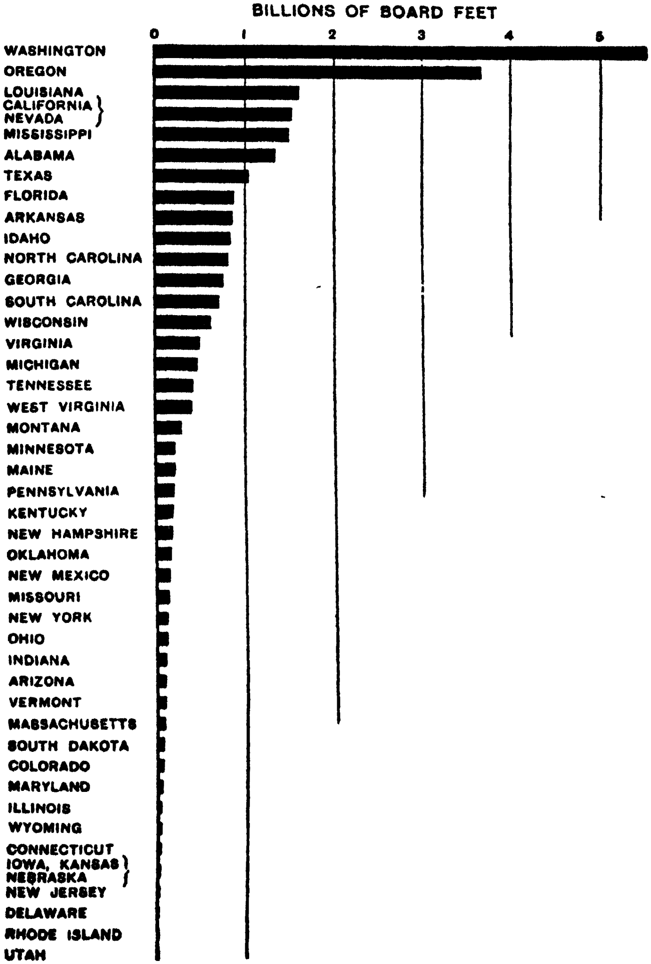

FIG. 92. — Lumber Cut by States, 1930. (From United States Bureau of the Census.)

and richer soils; they tend to replace the conifers when the latter are cut off. These include maples, birches, elms, oaks, and the devastated chestnut of the Appalachians. The better and less rugged lands of the region have long been claimed for farms and cities; in abandoned farmlands of New England the forest is returning, and the rugged contours of the Appalachians should be, for the most part, permanent woodland. Wisconsin and Michigan are at present the principal timber-states of the northern forest.

The Hardwood Forest

This bounds and blends with the northern forest at the southern limits of the latter. At the west, it follows the rivers into the prairie country. At the east and south, it meets the sandy lands of the Coastal Plain and the northern extremities of the Gulf States. Angiosperms which mix with the conifers of the North now dominate and become more numerous in species. The great fertile region of the Ohio Valley is the home of the black walnut, the hickories, the basswood, the yellow poplar, and many oaks. With more southerly range are the red gum and the tupelo gum, the former now cut in larger quantity than any other American hardwood. Among the few conifers is the red cedar. The Middle West will never be forest again, but more rugged areas in Kentucky and Tennessee cannot be denuded for many generations, and should never be. In the lower Mississippi Valley are the last stands of the virgin hardwoods. Mississippi and Arkansas, neither wholly within this forest region, are the principal timber-states of the hardwood forest.

The Southern Forest

This bounds the eastern portion of the United States, extending to the seaboard save where a narrow band of tropical forest is found in southern Florida, Louisiana, and Texas. It includes the sandy soils and "pine barren" lands of the Coastal Plain. The principal species are pines—eastern yellow pines—of which the chief species is the long-leaf pine; others are the slash, loblolly, and short-leaf pines, all valued in varying degrees for lumber and naval stores. Yellow pine, including all of these collectively, still furnishes the largest timber-cut of the United States (Fig. 94); as the land it occupies is mostly of little value for agriculture, there is little danger of its extermination. The bald cypress, one of the few deciduous conifers, finds its home in the swamps of the southern forest and the tropical forest. Hardwoods include red gum, tupelo gum, and ash. Nearly all the States within this boundary furnish a large lumber-cut.

The Rocky Mountain Forest

This is an area of high altitudes, with peaks extending above the timber-line, with arid lower lands where sagebrush and desert junipers struggle half-heartedly in the alkaline waste. The best forest species of this rugged land are Douglas fir (Fig. 93),

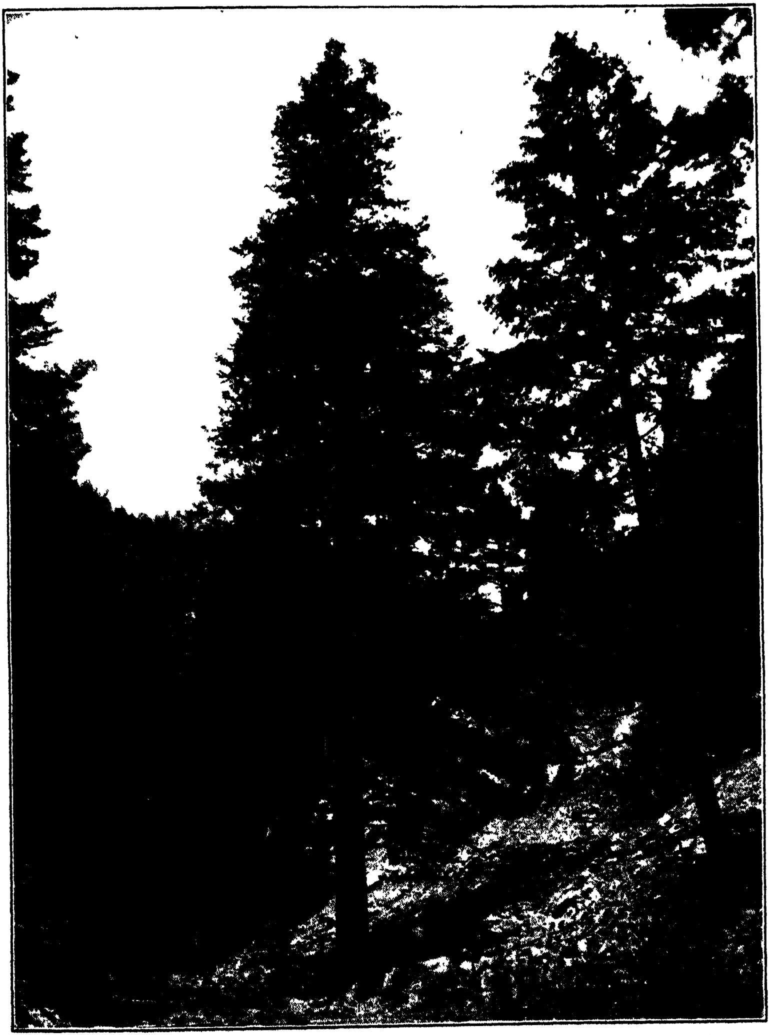

FIG. 93. — Douglas Fir (*Pseudotsuga taxifolia*), in San Isabel National Forest, Colorado. In the Pacific Northwest this species attains a massive size. (Photo from United States Forest Service.)

western yellow pine, and Engelmann spruce. In these high altitudes, with scant moisture, trees grow slowly. Lumbering is difficult and expensive. Great areas of lodgepole pine and firs are of little timber value. Aspen is the chief hardwood; cottonwoods, scrubby maples, and oaks occur. The most valuable timber areas of the Rocky Mountain forest are in Idaho and Montana, where occur larch, western red cedar, western hemlock, and firs.

The Pacific Forest

This is the region of superlatives. Here are found "the largest trees, the heaviest stands, and the largest remaining areas of virgin timber to be found in this continent." Chief of many important species is the Douglas fir of Oregon and Washington, sometimes yielding 250,000 board feet per acre. Redwood and sugar pine and western yellow pine are the principal timber trees of California. Hardwoods here are negligible; numerous oaks and some other species occur, but they are of little value save for fuel. Fig. 92 indicates the dominance of Washington and Oregon in present-day timber production, and Fig. 94 places the Douglas fir of this State second only to eastern yellow pine; considering the composite character of the latter, the claim of Douglas fir to rank first among timber species of the United States can scarcely be disputed.

The Tropical Forest

Here is a region rich in ecological interest but too limited in area to be of much timber value. Live oaks, picturesquely fringed with Spanish moss, extend northward into the southern forest; swamps are filled with the bald cypress; mangroves extend into tidewater and fringe the keys of Florida. Palmettos, found also farther north, mingle here with more tropical palms.

The Treeless Areas

These, shown in blank on the map, are mostly grasslands and arid deserts. The lack of trees in the prairie country of Iowa, the Dakotas, Nebraska, and Kansas is something of an ecological puzzle; contributory factors are probably a blazing summer sun and a constant wind-sweep which promotes in most tree-species transpiration in excess of water supply and invites the frequent prairie fires such as swept the country in Indian days. Along watercourses are found box-elders and cottonwoods, and settlers have effected local forestation with such resistant species.

3. The Woods Used for Lumber and Allied Purposes

Reference has already been made to various timber species. Fig. 94 indicates the quantity of various woods cut in this country in a single year, and the following discussion embraces a résumé of characters and uses of the principal species. It may be noted that lumber-trade names, such as "yellow pine," are often inclusive of several species; that some of them, such as "Oregon pine" used for Douglas fir, seem to the botanist to be troublesome misnomers. The tendency in the past has been to dress new and inferior species with names which suggest more valuable ones. In recent years, practice in the lumber trade has swung toward a more definite and standardized nomenclature, but very little scientific precision has yet been attained.

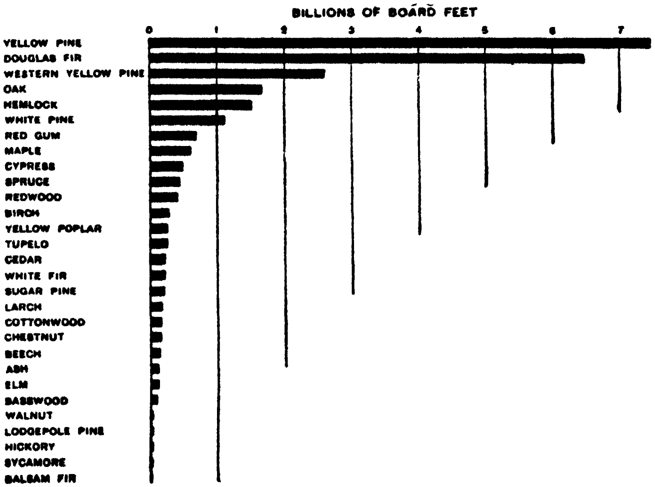

FIG. 94. — Lumber Cut, by Kinds of Wood, 1930. (From United States Bureau of the Census.)

The Softwoods

This valuable group of timber trees falls quite naturally into two classes: the soft, or white pines, and the hard, yellow, or pitch pine group.

THE SOFT PINES

These are rapidly growing species with soft light-colored wood, tinged pink in the heart and nearly white in the sapwood. The lumber is light, readily worked, but not strong or durable;

it dents and breaks readily and has little rot-resistance. Old trees, whose limb-scars have long been overgrown, yield valuable clear (knot- and blemish-free) lumber prized for paneling, interior finish, planing-mill products and millwork. There is little difference between spring and summer wood (Fig. 95*A*); therefore the grain is not conspicuous and much of the celebrated pine paneling, mantels, and carving of colonial days was paint-finished. Inferior and second-growth pine is much blemished by knots whose pinkish color contrasts strongly with the lighter background. Being very pitchy, these tend to stain through paint and varnish unless sealed with shellac. Great quantities of low-grade white pine are used in boxes and crates.

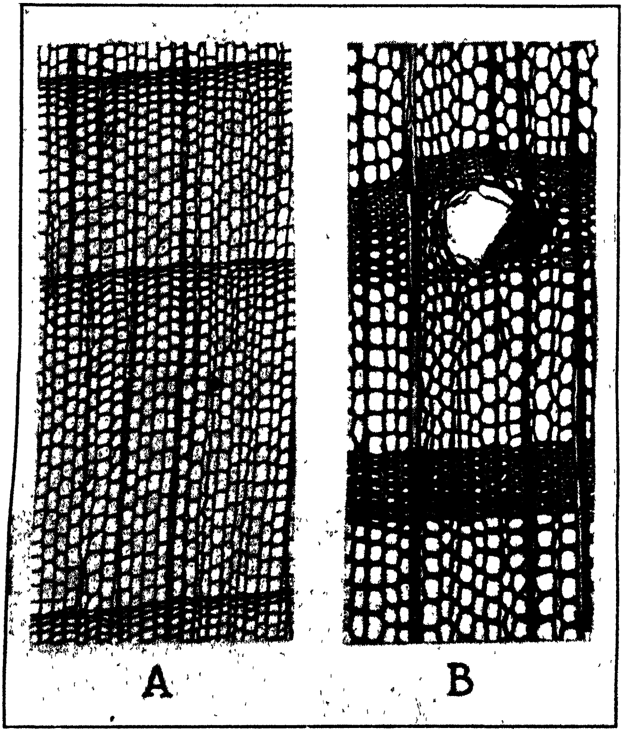

Fig. 95. — Soft and Hard Pines. *A*, Eastern White Pine (*Pinus Strobus*); *B*, Southern Yellow Pine (*P. palustris*). (Photomicrographs from United States Forest Products Laboratory.)

White pine has a number of specialty uses. It is the chief wood used for shade and map-rollers—a more important employment than might be supposed—for small woodenwares where strength is not essential, for matches, and for patterns and flasks in foundries.

The principal white pines are the Eastern White Pine (*Pinus Strobus*) (Fig. 80), and the Sugar Pine (*P. Lambertiana*) of southern Oregon and California. The latter is the most massive of North American pines. *P. monticola*, the smaller Western White Pine, is of minor significance.

THE HARD PINES

Wood of the principal species in this group is heavy, coarse grained, in some kinds so hard that the term "softwood" is a misnomer, and in others approaching the white pines in consistency. The denser species have marked distinction between thin-walled spring and thick-walled summer wood (Fig. 95*B*), giving a pronounced grain-pattern (Fig. 96); the tissues are high in pitch or oleoresin. A discussion of the turpentine values of these pines will be found in Chapter V. Yellow pine, including several southern species, ranks first among timbers cut in this country. It is used for heavy timbers, scantlings, finish, flooring, planing-mill products, car construction, boxes and crates, siding and roofing, concrete forms, and a vast number of other purposes. For exposure to scuffing or moisture, as in flooring, yellow pine should be rift-sawed; thus the dense bands of summer wood protect the alternating stripes of soft spring wood. Slash-cut pine flooring wears in "scallops" where the spring wood scuffs out, and moisture between rings bring about splintering.

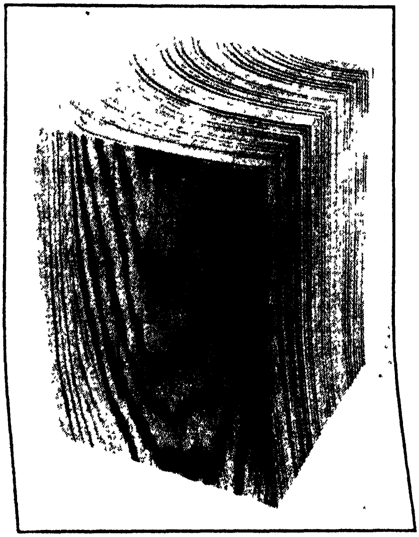

FIG. 96. — A Cube of Southern Yellow Pine. (From United States Forest Products Laboratory.)

The principal yellow pines of the southern group are Longleaf Pine (*Pinus palustris*) which is the yellow pine par excellence, Loblolly or Oldfield Pine (*P. Tæda*) (Figs. 97, 98) a very

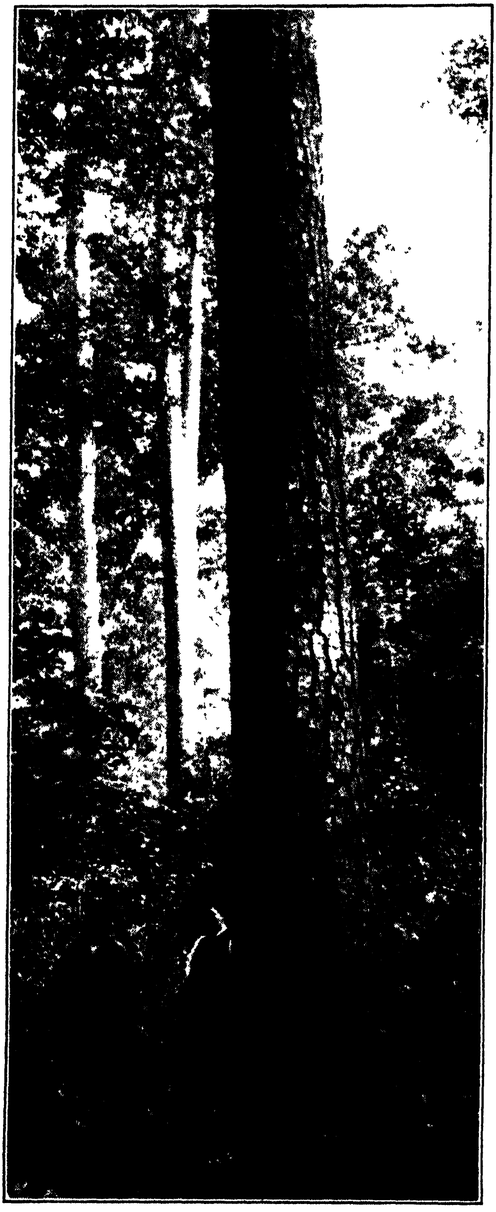

FIG. 97. — Loblolly Pine (*Pinus Taeda*). A rapidly growing species of the Southern States. This tree is about one hundred years old. (Photo from United States Forest Service.)

rapidly growing but inferior species, and Slash Pine (*P. cubensis*), also a rapidly growing species which tends to replace the long-leaf. Softer species, of more northern distribution and less use, are Norway Pine (*P. resinosa*) which, being resistant to blister rust, is being used for reforestation where otherwise *P. Strobus* would be chosen, and Pitch Pine (*P. rigida*), a common but not valuable tree of eastern sandy soils.

Of the western yellow pines, chief is Western Yellow Pine (*P. ponderosa*), of wide distribution, growing to massive size in the Sierras. Lumber of this species has been marketed as "California white pine"; under provisions of recent Federal legislation, attempt is being made to enforce the use of the more definitive term "ponderosa pine." Its near relative, Black or Jeffrey Pine (*Pinus Jeffreyi*), is abundant and local in the mountains of California. Lodgepole Pine (*P. contorta* var. *Murrayana*), is a widespread but small and not very valuable tree of the Rocky Mountain forest and the higher altitudes farther west.

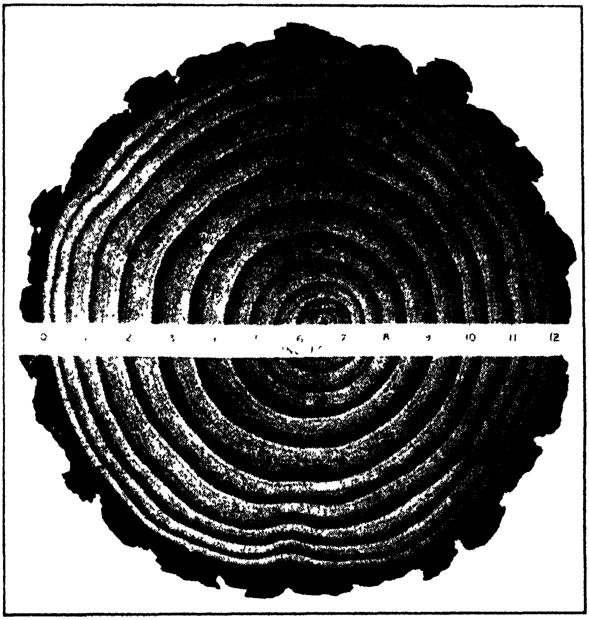

FIG. 98. — Loblolly Pine (*Pinus Taeda*). Growth of twelve inches in diameter, inside the bark, in twelve years. This shows the extremely rapid growth of loblolly pine under favorable conditions. (Photo from United States Forest Service.)

OTHER CONIFERS

Douglas Fir.—The dominant single species timber of the United States and Canada is *Pseudotsuga taxifolia,* Douglas Fir (Fig. 93), also known as Oregon Pine, the chief lumber product of Oregon and Washington. Next to the sequoias, which it rivals, it is the most massive of American forest growths; its ancient and scarcely tapered trunks yield timbers two feet square and from one to two hundred feet in length. The wood is rather variable in density; when well grown it is light, stiff, and strong, without a rival for such exacting purposes as bridge-building, masts, and spars. Great quantities are used in all sorts of construction. Grain-pattern, particularly when slash-cut or in rotary veneer, is striking; Douglas fir is succeeding southern yellow pine in interior varnished trim but is scarcely hard enough to rival it for flooring. Its natural color is pale pink, becoming pale yellow; among its few defects are pitch-pockets and a tendency to splinter. Among the specialty uses are tank, silo, and pipe-staves; it is also used in boat-building.

Hemlocks.—The most widely known species is Eastern Hemlock (*Tsuga canadensis*), although much larger quantities of Western Hemlock (*T. heterophylla*) are at present lumbered. Hemlock is slow-growing, weak, coarse-grained and "brash" lumber, marred by knots and wind-shake (the latter a circumferential splitting frequently found between annual rings in old hemlocks). It also shows a tendency to heartwood decay. Among its few redeeming qualities are decay-resistance in contact with soil somewhat greater than that of other cheap Eastern softwoods. Hemlock is mainly used for cheap and concealed construction purposes, cheap millwork, boxes, and crates. The use of hemlock bark in tanning is discussed in Chapter V.

Spruces.—These are various species of *Picea*; their quality is rather variable. Spruces of the east are mostly rather small trees of second growth, knotty, inferior, used mostly for pulpwood. Clear spruce is usually soft, not strong, and light in color; selected grades have a springy resilience of value in paddles and airplane construction. Ordinary grades are used for cheap construction, millwork, boxing, etc. *Picea sitchensis,* the Tideland Spruce of the Pacific Northwest, is the source of nearly half the spruce lumber now cut, and furnishes nearly all the high-grade spruce of the present day.

Firs.—Most valuable of the firs is the Red Fir (*Abies magnifica*) of California, which furnishes the principal supplies of this rather unimportant group of conifers, being shown under the heading "White Fir" in Fig. 94. The wood is reddish, soft, close-grained, and very durable in soil-contact. The Eastern Balsam Fir (*A. balsamea*) is soft and inferior, with little to recommend it save cheapness.

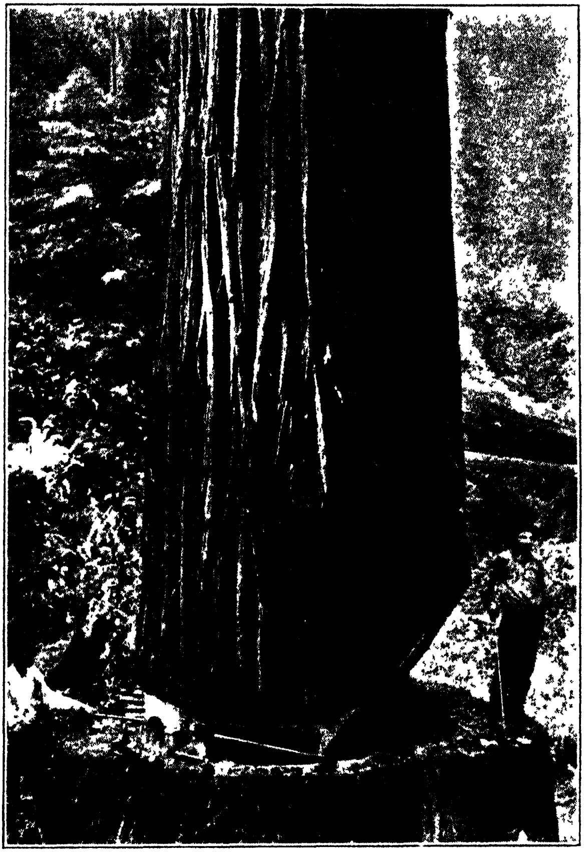

Fig. 99. — The Felling of a Large Redwood. Wedges are driven into the saw-kerf on the left, and the tree falls in the direction of the under-cut on the right. (Photo from United States Forest Service.)

Cypress.—While gymnosperms which bear this "common name" are several, cypress timber is nearly all from *Taxodium distichum,* the Bald Cypress, a most characteristic tree of the swamps of Louisiana, Florida, and other parts of the South. The wood is light, soft, and not particularly strong; its principal "selling strength" is in a celebrated rot-resistance. Cypress is much used for cooperage, railway ties, posts, ship-construction, pipe and silo staves, decking and outdoor flooring, and in caskets and coffins.

Redwood.—This is almost wholly from *Sequoia sempervirens* (Fig. 99); *S. gigantea,* the Big Tree, is rare and local in distribution as well as commercially unimportant. The wood of redwood is soft, light, very straight-grained, and not particularly tough. Once regarded as most inferior, it is now in demand for a variety of purposes. It works easily, polishes well, and is mostly employed for doors and other millwork. It is extremely rot-resistant (Fig. 100); old trunks remain in contact with the soil for hundreds of years without decay. The name "redwood" comes naturally from the bright pink color of the heart; the sapwood, which in old trees is very thin, is, like nearly all sapwood, almost white. Burl redwood is in great demand for interior finish.

An interesting commentary on one value of redwood is given by Jepson.[5]

> "Although San Francisco has a dry climate and is a city of frame houses, it never had a general and widespread conflagration until April, 1906, when the water-supply was suddenly and absolutely cut off by earthquake disturbance. This immunity from fire was due to the fact that most of the houses were built of Redwood. As a protection against fire the wood has two superior qualities; it does not ignite readily, burning slowly at first, and it is so spongy that it absorbs a stream of water from a fire-hose with marked avidity."

The mention of redwood almost necessitates some discussion of the future of the species. Thanks to public-spirited effort, considerable areas of the massive and ancient trees have been preserved for posterity in parks and reservations, and probably other valuable areas will be likewise conserved. Despite rapid and in some cases wasteful exploitation, large areas of redwood remain and afford a considerable annual supply of this timber. Redwood, unlike most conifers, sprouts readily from the root, and there seems no likelihood of its extermination under present forest policies in California.

Cedars.—This name is shared by several species, of several genera. All may be classed as specialty woods; qualities which they have in common are rot-resistance and aromatic properties due to volatile oils, which repel insects. Largest in quantity is the massive Giant Cedar or Western Red Cedar (*Thuya plicata*) of Oregon and Washington, whence come red cedar shingles. Port Orford Cedar (*Chamæcyparis Lawsoniana*), a local tree of Oregon and northern California, is valued for herbarium cases and other insect-repellant containers. More celebrated in "cedar chests" is the brilliantly colored wood of Eastern Red Cedar (*Juniperus virginiana* and *lucayana*). Its scent is still noticeable in panels which were put in place in England about 1666. Eastern red cedar is of smooth, even grain, well fitted for carving; its quality is unrivalled for one special use—"pencil cedar."

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[5] W. L. Jepson, *The Silva of California* (University of California Press, 1910), p. 135.

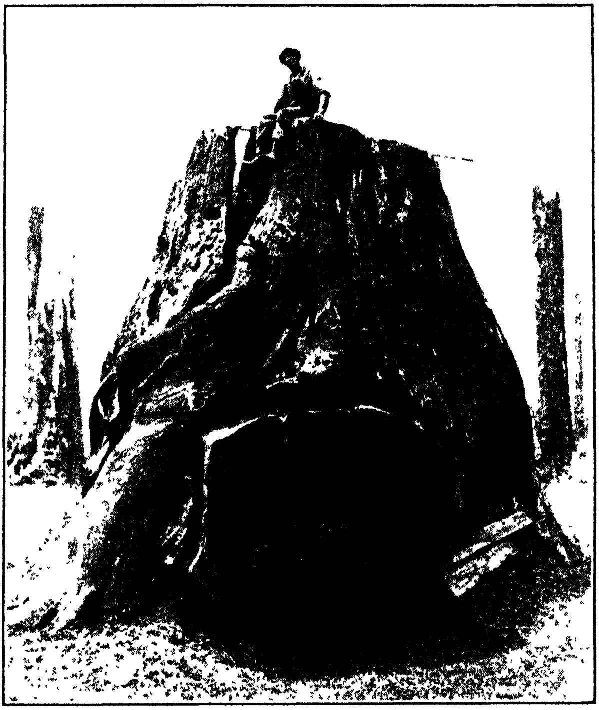

FIG. 100 — Rot-Resistance of Redwood. The log shown in section has been prostrate over a thousand years, yet the heartwood is still sound, and has been used for timber. The upright trunk may have been a sprout from the prostrate one. (Courtesy of Patterson Pictures.)

The Hardwoods

Hardwoods are cut in much smaller quantity than conifers. They are, in general, more expensive and more difficult to work; they are not much used for the rougher purposes of construction and timbering, but are employed in floors, finish, furniture, and specialty products.

AMERICAN HARDWOODS

Oaks.—*Quercus,* the Oak, is largest and most widely distributed of American tree genera. Of nearly fifty species, some are mere shrubs; others are forest giants. The genus is commonly divided into the White Oaks, typified by the Eastern White Oak (*Quercus alba*) and the Chestnut Oak (*Q. Prinus*), and the Red or Black Oaks, of which Red Oak (*Q. rubra*), and the Texas Red Oak (*Q texana*) are principal examples. Both groups afford hard, heavy, tough, strong, and proverbially durable timber; the white oaks in general are preferred. The wood color usually is rather light, sometimes with dark mottlings in the heartwood. Broad rays, large vessels in bands visible to the eye, and plainly marked rings afford striking patterns in any exposure (Fig. 101). Oak leads as hardwood flooring material; for finish and furniture it is still much used, although in expensive construction and furniture it has been largely replaced by darker and less garish materials. Oak finds employment in shipbuilding, ties, wheel-spokes, and cooperage; for tight cooperage, for reasons previously mentioned, white oak is unexcelled. Inferior oak is largely used for posts and is highly valued as fuel.

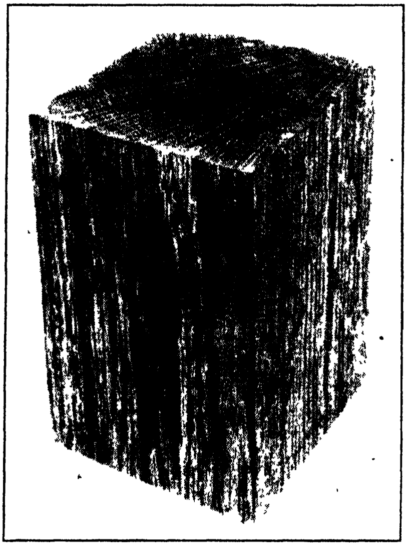

FIG. 101. — A Cube of Oak. (Photo from United States Forest Products Laboratory.)

Arkansas leads in oak production, closely followed by Tennessee and Louisiana.

Chestnut.—This is the wood of *Castanea dentata,* a species which will be further discussed (Chapter V) as a source of tanning material. Its timber is among the lighter hardwoods; it is soft and rather weak for constructional purposes, likely to check and warp in drying, reddish or yellowish brown in color, not very pleasing in figure. Chestnut is decay-resistant in the soil and will be difficult to replace for ties, poles, and posts. Considerable quantities are used in veneer-cores (Fig. 74), in cheap furniture, and in crating. It has been the chief wood used for such varied purposes as musical instruments, caskets and coffins, and toy-making.

Beech.—The wood of *Fagus americana* is hard, strong, tough, very close-grained, and difficult to split; it is pale red with thick, lighter sapwood, with broad rays which make a garish pattern when quarter-sawed. The largest quantities of beech are used in planing mill products, millwork, and crating. It is found in cheaper furniture and chair stock. Being almost tasteless, it is valued for wooden spoons and butter-working machinery; the old-fashioned chopping-bowl was of beech. Brush-backs and other small, necessarily tough articles are largely made of beech.

Pennsylvania leads in beech production.

Birch.—Several species of *Betula* considerably resemble the maples in texture, being close-grained, without striking figure, and quite dense and hard. Yellow Birch (*Betula lutea*) is the principal species; next comes Sweet, Black, or Mahogany Birch (*B nigra*). Both are extensively used in furniture and veneers, being often stained in imitation of mahogany or walnut. Birch is much used for small woodenwares, and is the principal wood used in making shuttles, spools, and bobbins.

Walnut.—The chief walnut of the American market is Black Walnut (*Juglans nigra*), a noble tree of the Ohio country, whose supplies have been decimated by civilization. Perhaps the most celebrated of American furniture woods, it brings the highest price per unit of any of our forest staples. The wood is dark brown, rich in color and lustrous; it is hard and tough and not likely to warp in use. It takes varnish and glue well, and is, all in all, an ideal furniture wood. The color is rather sombre; the grain-figure wonderfully varied. The best walnut is mainly used in veneers. Finish consumes large quantities. A sewing machine framed in anything else (except red gum) would be scarcely imaginable. Musical instruments (probably chiefly pianos) take toward 20 per cent of the annual walnut cut. Gunstocks are almost invariably of walnut.

Hickories.—These trees (*Carya* spp.), closely related to walnut, are among the strongest and toughest of American woods. Hickories are among the few timbers whose sapwood is preferred to heartwood, though it appears that this preference rests on opinion rather than reason. In horse-and-buggy days, hickories led in manufacture of vehicles and vehicle parts, and they are now highly valued for automobile spokes. Handles of all sorts are made of "choice second-growth hickory."

Maples.—In quantity cut, the maples rank next to the oaks among staple hardwoods, though passed in recent years by a furniture upstart, red gum. Sugar Maple (*Acer saccharum*) is the principal species. It is hard and dense, close-grained, with very small pores (Fig. 102), and (save in specialties such as bird's eye and curly maple) of inconspicuous grain. It wears well underfoot and ranks next to oak as a flooring hardwood, exceeding that wood where cheapness rather than appearance is desired, as for mill-flooring and for some types of public building. Maple is an excellent furniture wood, and has other widely scattered uses. Nearly all our boot and shoe findings are made of maple.

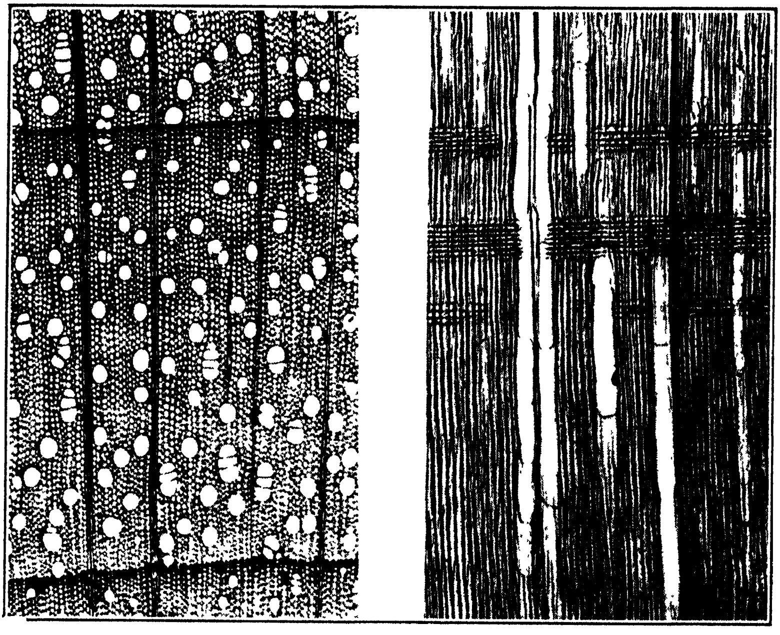

FIG. 102. — The Dense, Finely Diffuse-Porous Wood of Sugar Maple (*Acer saccharum*), in Cross- and Radial-Section. The sap used in maple syrup and sugar-making travels in the numerous small vessels. (Photomicrograph from United States Forest Products Laboratory.)

Red Gum.—This is the wood of *Liquidambar styraciflua* (Fig. 103), also known as Sweet Gum, which recently, as a single species, has attained first place in the American hardwood-cut. It is reddish brown in color, often with darker streaks, with

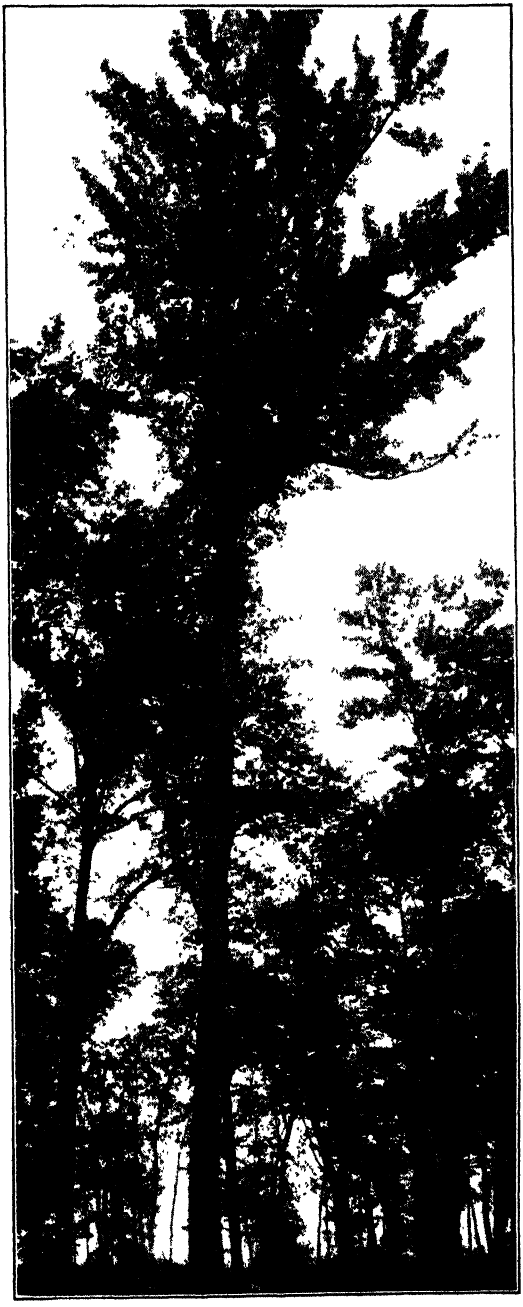

FIG. 103. — A Tall Red Gum (*Liquidambar styraciflua* in Tennessee. (Photo from United States Forest Service.)

indistinct annual rings and not usually striking figure. It is softer and weaker than most furniture woods which have been mentioned above and likely to warp if not properly handled. It is readily worked, and largely used for finish, under its own name in cheap work, and for inconspicuous parts and veneer-cores in high-priced furniture. It is extensively used for cheap veneers and panelings. From walnut and mahogany, which it is often stained to imitate, it can be distinguished by its smaller pores and less sharply marked figure (Figs. 103, 104, 105).

Louisiana leads in cut of red gum.

Other American Hardwoods.—These are numerous, but few are of sufficient interest for detailed mention. Yellow Poplar (*Liriodendron tulipifera*), Basswood (*Tilia glabra* and *T. heterophylla*), and the Cottonwoods (*Populus* spp.) are among the softest of American hardwoods, light in color, and without conspicuous grain. Among their chief uses are paneling, carvings, drawer-bottoms, plywood, and excelsior.

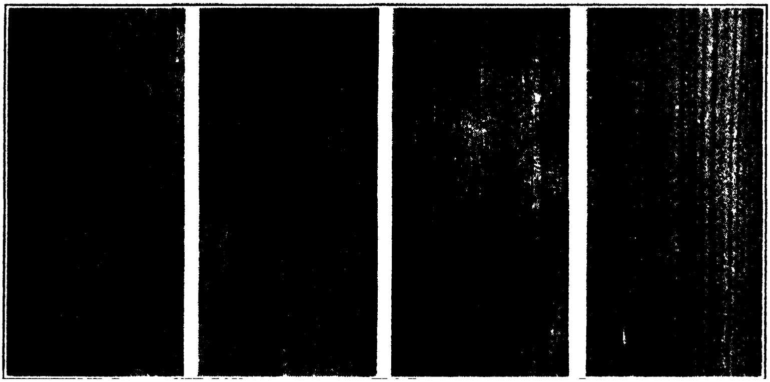

FIG. 104. — Figures of Walnut and Red Gum. From left to right, walnut plain-sawed, red gum plain-sawed, walnut quarter-sawed, red gum quarter-sawed. (Photos from United States Forest Products Laboratory.)

The elms (*Ulmus* spp.) are noted for their toughness, but they are of uneven grain and difficult to work. Tupelo Gum (*Nyssa* spp.) is somewhat similar to red gum, variable in quality, often inferior, used for veneer-cores and panelings.

Ash (*Fraxinus* spp.) is of several species whose qualities decidedly differ. White Ash (*F. americana*) has an enviable reputation for toughness, being used in airplane parts, oars, baseball bats, snowshoes, etc.

FOREIGN HARDWOODS

These are not largely used in America save in furniture and expensive finish, veneers (Fig. 68), etc.

Mahogany.—This is among the most celebrated of furniture and finish woods; the name properly belongs to *Swietenia Mahogani* of the West Indies and Central America. It has been extended to another tree, *S. macrophylla* of Mexico and Central America, and, still further, to African species, some of the Mahogany Family (Meliaceæ) and some not. True mahogany is from pale to deep reddish brown, finely porous, with distinct but not garish rays. The beauty of mahogany is due more to its light-

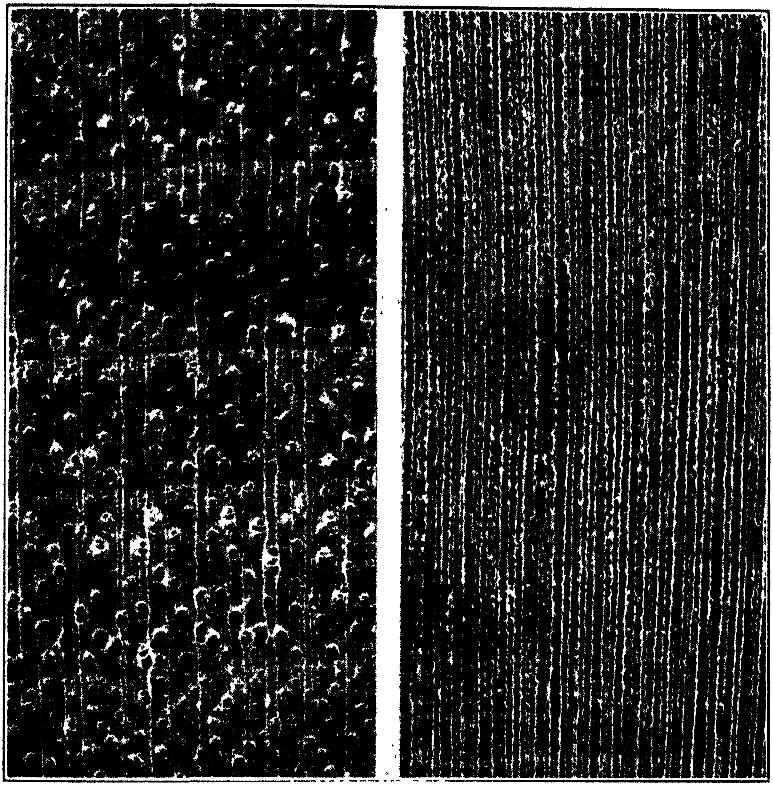

FIG. 105. — End-Grain Appearance of Walnut (left) and Red Gum (right), Both Enlarged. In the red gum, the annual delimitations are scarcely visible, and the pattern exposed on sawing is much less evident than in walnut (Fig. 104). (Photos from United States Forest Products Laboratory.)

reflecting qualities than to actual variations of cellular structure. One of the most distinguishing characteristics of mahogany comes from the reflection of light on the rays in radial section; these, according as the light strikes them, may seem lighter or darker than the background of fibrous tissue. Mahogany is varied in figure, not given to shrinking in use, and is insect-repellent. It takes stains readily and is offered in a variety of finishes. Considerable quantities are used in airplane manufacture for propellers, for interior car-finish, caskets and coffins, musical instruments, and for a variety of applications.

In an attempt to differentiate true mahogany from the various species offered in imitation, more distinctive names have recently been advocated for the best-known of these products. Among these is *khaya,* from the African genus of that name, which supplies the best African mahoganies. Mahogany and khaya collectively are the largest exotic cabinet timber imports of the United States. Under the name "Philippine mahogany" several dark reddish woods of the genus *Shorea* of the Dipterocarpaceæ have recently appeared in the American market. For these, the United States Forest Service advocates the names *tanguile, red lauaan,* and *almon.*

Spanish Cedar.—This wood ranks next to the mahoganies as a cabinet and furniture import. It is from *Cedrela odorata* of the Meliaceæ, and thus is related to the true mahoganies. It is of reddish brown or red heartwood, with darker inclusions, and strongly aromatic. Some years ago nearly the entire import—some 30,000,000 board feet—was used in making cigar-boxes; it is stated that the porous nature of the wood aids cigars to season and that the odor improves their flavor. As to the first value, a jack-knife dissection of the ordinary cigar-box usually reveals a paper-thin veneer of Spanish cedar glued over a core of basswood or yellow poplar. In recent years Spanish cedar has been somewhat used in airplane construction; it is a beautiful but not commonly seen cabinet wood.

Ebony.—Several hard, heavy, dark heartwoods bear this name; the best is that of *Diospyros Ebenum* of India and Ceylon, a relative of our own persimmon. Pearwood is sometimes stained black in imitation of ebony. Ebony is used in inlaid work; for the black keys of pianos; for flutes, whips, canes, umbrella and knife handles, and various other specialties.

Boxwood.—In color contrast with ebony comes the heavy, dense, tough wood of *Buxus sempervirens,* a slow-growing evergreen much used for landscaping. Boxwood seasons slowly, being usually kept in dark cellars for three to five years to prevent checking. When thoroughly dried, it takes a beautiful polish and does not expand or contract readily. It is thus suitable for rulers and other mathematical instruments; for musical instruments, shuttles, spools, and bobbins. Woodcuts are done on boxwood. It is much used for turning and carving. Supplies come chiefly from southern Europe.

Rosewood.—Dalbergia nigra of Brazil furnishes a dense, dark brown to almost black wood with roselike odor (hence the name) and beautiful variations of grain. Rosewood furniture is at present somewhat out of vogue, but the timber is occasionally employed in cabinet work, scientific instruments, etc. It is of oily character and takes glue with difficulty.

Lignum Vitæ.—This is the heartwood of *Guaiacum officinale* of the West Indies and *G. sanctum* of tropical America. It is dense, tough, hard, and resinous, the heaviest of commercial woods. A cubic foot weighs 76 pounds. No other wood equals lignum vitæ for bowling balls, mallet-heads, pulley-sheaves, and other special purposes where the utmost in durability is essential.

Balsa.—At the other end of the weight-scale is the nearly colorless wood of *Ochroma Lagopus* (Fig. 61*A*), a South American product of the Bombacaceæ. It consists largely of thin-walled wood parenchyma; its specific gravity (0.2) is even less than that of cork. Unheard of a decade or two ago, it is now in demand for purposes where extreme lightness is the desideratum. Large quantities of waterproofed balsa are used as floats and life-preservers; balsa floats buoyed mines in war-time. Among its most popular applications is in the making of model airplanes; it is also used for more serious purposes in aircraft. Balsa finds some application in insulation. Balsa furniture, made the more innocuous by special joints, crashes realistically but not fatally upon the heads of villains in battles of the "movies."

CHAPTER V

FOREST PRODUCTS: RESINS, TANNING MATERIALS, AND CORK

The present chapter deals with a rather miscellaneous group of products of forest origin which play a prominent and often unrecognized part in the life of every day. With the exception of cork and some tanning materials most of those to be discussed are of American origin.

1. RESINS AND RELATED PRODUCTS

The Nature and Occurrence of Resins

RESINS are a group of plant-formed substances of complex nature, whose structure is not well understood. They are large-molecular compounds of carbon, hydrogen, and oxygen; the latter in relatively small amount. They are amorphous and vitreous, more or less transparent or translucent, and generally of yellowish or brownish cast. They are practically insoluble in water, but they dissolve readily in most of the common organic solvents, such as alcohol and ether. Within the plant they often occur in solution in VOLATILE OILS of the terpene group, or less commonly with GUMS, the combinations being known as OLEORESINS and GUM RESINS.

Oleoresins occur in a considerable number of plant families. Those best known and most widely used are mainly from the Pinaceæ. Oleoresin canals occur in the wood of many conifers, and also in the bark and leaves. The pinaceous oleoresins of commerce are mainly derived from the newly formed wood of the trunks.

So far as is known, the resins play no vital part in the ordinary life of the plant. Being, like fats, low in oxygen, they are potentially concentrated sources of heat-energy. Like fats, they burn readily; but, unlike fats, their oxidation takes place only at high temperatures and not, apparently, in the ordinary course of metabolism. Oleoresins exude readily from wounded tissue; their volatile constituents evaporate, and the resin is left as an impervious and protective varnish, which delays drying of thin-walled tissues and prevents the ingress of wound-invading fungi. Resins are antiseptic and decidedly resistant to decay-agencies; amber and kauri are found as fossil remains of long-dead conifers whose cellular structures disintegrated in ages past.

The Naval Stores Industry: Rosin and Turpentine

A number of species of pine, particularly the Long-leaf Pine (*Pinus palustris*), (Fig. 95*B*), the Slash Pine (*P. cubensis*) of the southern United States, and the Maritime Pine (*P. maritima*) of France and southern Europe, furnish commercial oleoresins in quantity. Resin canals are numerous, both longitudinally among the tracheids and horizontally in the rays; they form an intricate system in the xylem from which the oleoresin often saturates limited regions in the wood. It also fills internal cracks and exudes from wounded surfaces. The exuding oleoresin is known as pitch, or, when obtained for distillation, as crude turpentine. Pitch and tar, the latter obtained by incomplete combustion (destructive distillation) of the wood of long-leaf pine were from the very beginning of Southern settlement important commodities and exports. From the use of pitch and tar in calking wooden sailing ships and in waterproofing rigging and hawsers, these products derived the name of NAVAL STORES, and the term still attaches to an industry whose chief products are now used mainly for purposes quite different than the nautical. In importance, the naval stores industry ranks only behind lumbering and wood-pulp in American forest industries. Its chief products today are rosin and spirits of turpentine—the residue and the distillate, respectively, of the distillation of crude turpentine.

TURPENTINING

Chipping.—Crude or gum turpentine is obtained by chipping the tree trunks and collecting the exudate. With a U-shaped gouge called a hack (Fig. 106) V-shaped channels or streaks are cut on a portion of the circumference—the face. In early practice, a box, or cavity, was cut at the base of the tree; the turpentine flowed downward into this and was dipped out from time to time. Trees with this deep wound at the base are subject to windfall; the box, encrusted with highly inflammable pitch, is readily burned out by ground-fires which cause severe or fatal injury to the tree. Boxing is now almost wholly replaced by the cup-and-gutter system which originated in France. It was introduced into the United States about 1894 but did not come into extensive use till about a decade later. The gutter consists of a V-shaped metal trough, inserted or attached just above an earthen or metal cup into which the flow is directed. The cup is much more easily handled and cleaned than the box, and the yield by the more modern process is larger and of better quality; the saving is said to approximate 20 per cent.

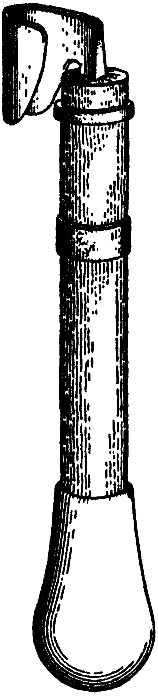

FIG. 106. — Hack used in Turpentining. (From Schorger and Betts, United States Department of Agriculture Bulletin 229).

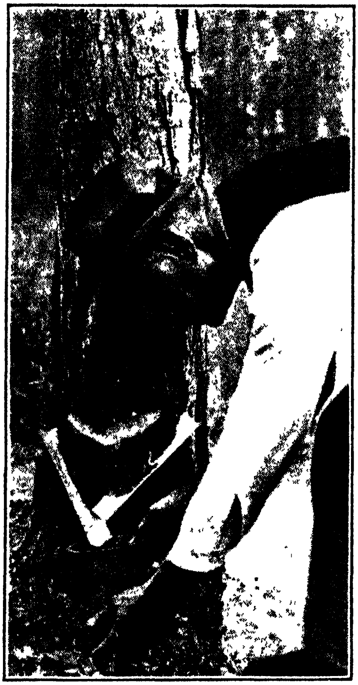

FIG. 107. — Turpentining. The first cut or advance streak has been made, the gutters set, and the cup is being put in place. Gum from these initial wounds — the "virgin dip" — yields the best grade of water-white rosin. (Photo from United States Forest Service.)

The flow of gum turpentine commences as soon as the streak is cut, and nearly 90 per cent of the exudation occurs within the first three days. With the passing of the first few hours, the severed ends of the resin canals gradually become plugged with hardened gum. Presently the flow ceases, and the further secretions of gum diffuse into the wood. After about a week the flow is started again by widening the streak with the hack. Removal of a quarter of an inch of new wood is all that is necessary, but generally a considerably broader area is taken off. The season usually begins in March and continues till October or November, after which the flow of pitch ceases. The number of chippings per season is from twenty-eight to thirty-five. Experiments indi-

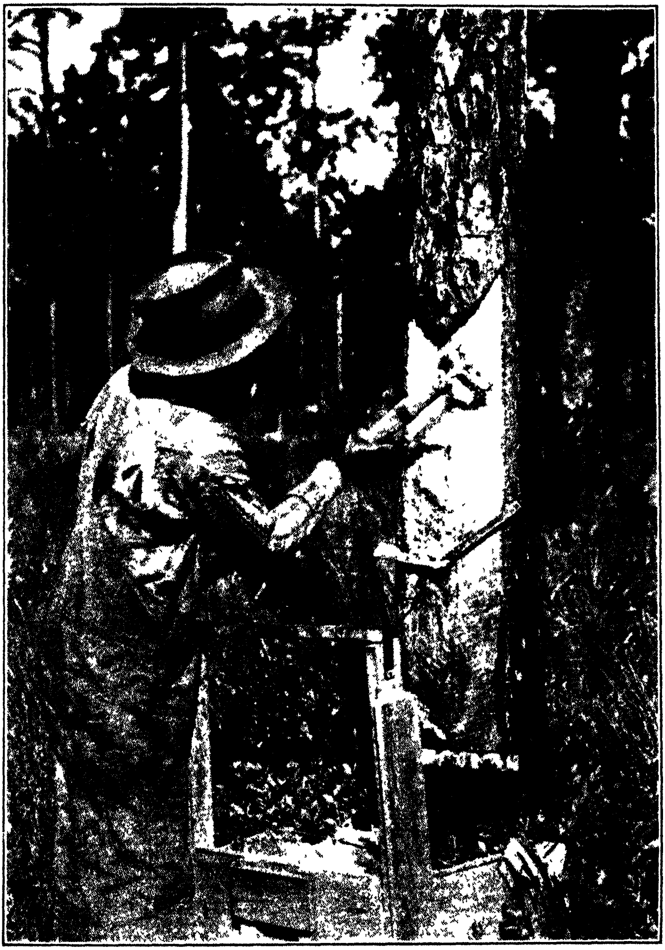

FIG. 108. — Turpentining. Removal of the "scrape," or hardened gum at the end of the season. This gum has partially air-dried from exposure; it yields little turpentine and a poor grade of rosin. (Photo from United States Forest Service.)

cate that shallow chipping, which removes not more than half an inch of wood, is most desirable. Trees may be worked from five to seven years. By improved practices, the number of productive years may be considerably lengthened. Naturally, wounding, interference with water-transportation, and removal of bark hinder the growth of the trees somewhat, and some damage occurs from windfall and insect attack. When the turpentine yield becomes unprofitable, the forest may be cut for lumber.

Distillation.—The boxes or cups are emptied several times in a season, and at the end of that time the exuded gum is scraped off the face. The crude turpentine contains about 20 per cent of spirits of turpentine, 65 per cent of rosin, 5 to 10 per cent of water, and some bark, dirt, etc. As the face goes higher, the distance between flowing surface and box or cup increases (unless the cup be moved higher). Evaporation increases with the distance of drip, and gum that has flowed farthest runs lowest in spirits.

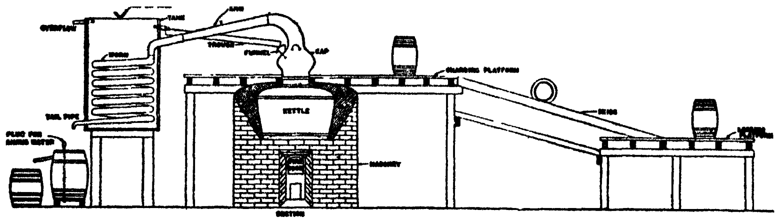

FIG. 109. — Diagram of a Turpentine Still. (From Schorger and Betts, United States Department of Agriculture Bulletin, 229.)

A turpentine still (Figs. 109, 110) is a comparatively simple piece of apparatus. It usually consists of a kettle holding about fifteen to twenty barrels. This kettle has a removable cap connected by a long tubular arm to the worm, which consists of a spirally coiled tube surrounded by a tank of water. It leads to a tail-pipe from which the distillate drips into a container. The kettle is mounted on a furnace of masonry and sheltered by a rough board shack.

The still is charged by pouring in a sufficient amount of gum, and the joints are connected and made steam-proof with clay. The fire is then started and distillation begins. The water of the crude gum and the spirits of turpentine vaporize, condense in the worm, and drip into the container. The small amount of water in the gum soon distils, and more is added from the cooling-tank by means of a trough communicating with a funnel in the cap. About two and a half barrels of water are usually needed for a twenty-barrel still, and the distillation is complete in from two to two and a half hours. After the original water of the gum disappears, there is some danger of the ebullition of boiling

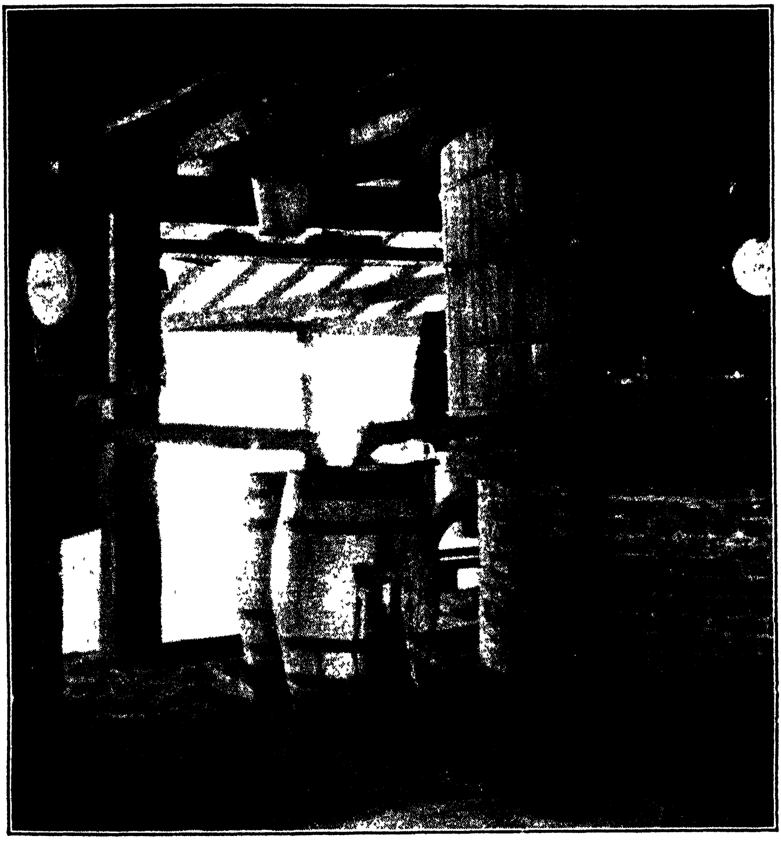

FIG. 110. — Turpentining. Interior view in a still-house, showing cooling-tanks, collecting-barrels, and thermographic apparatus for recording still temperatures. (Photo from United States Forest Service.)

oleoresin into the cap and worm; this is prevented by skilful management of the temperature and the addition of suitable quantities of water. Contrary to what might be supposed, rapid heating of the mass is less conducive to foaming over than is slow heating. Distillation is not usually carried to completion; the best grades of rosin still contain a little turpentine.

In French practice, steam stills are used to some extent; in these the water is boiled in a separate container and the live steam is conducted through the still proper. This steam process yields a better product, but the apparatus is more expensive and complicated and has not come into general use in this country.

Treatment of Turpentine and Rosin.—The distillate, consisting of water and spirits of turpentine condensed from vapor within the worm, drips into a container, usually an ordinary barrel. Water and spirits of turpentine—usually referred to simply as "turpentine"—are immiscible and soon separate; the turpentine, being lightest, comes to the top. Water is drained off from time to time through a pipe in the bottom of the barrel, and the turpentine is removed from the top. Turpentine is sold in white oak barrels which have been thoroughly treated with glue to prevent leakage.

The hot residue of rosin in the still is skimmed to remove chips, needles, and other trash, and it is then run out through a series of screens into a vat. When partially cooled, it is dipped from the vat into barrels and allowed to harden. Rosin is graded according to its color, the nearest white being most valuable. The best grade is obtained from the first streak—the virgin dip—and is known as water-white or "W. W." The darkest and least valuable is from the scrape.

Distillation of Wood.—Pine wood, and pine wood wastes, are distilled to some extent by two general processes. Destructive distillation consists in heating the material to a high temperature out of contact with air; the products are wood turpentine, a complex product known as pine oil, pine tar, and charcoal. By steam distillation, wood turpentine, a smaller quantity of pine oil, and wood rosin are obtained. Wood turpentine is similar to that obtained from gum turpentine, but it has a peculiar odor and generally sells at a lower price.

Production of Turpentine and Rosin.—The naval stores industry is localized from the Carolinas through Georgia and Florida to Texas; about 80 per cent of the domestic production comes from Georgia and Florida. The commercial center of the industry is Savannah.

Pine lands serviceable for turpentining are being rapidly depleted, but the industry as a whole still shows a fairly uniform annual output. It is probable that in future years the Western Yellow Pine (*Pinus ponderosa*) may be utilized for turpentining, particularly in its southerly range in California and Arizona. Experimental tapping of this species has given promising results.

TABLE II

Turpentine and Rosin, Industrial Consumption, for Years Shown

INDUSTRY	TURPENTINE			ROSIN		
	AVERAGE 1925–1929	1930	1931	AVERAGE 1925–1929	1930	1931
	Gallons	*Gallons*	*Gallons*	*500-pound barrels*	*500-pound barrels*	*500-pound barrels*
Automobiles and wagons	211,779	80,953	87,072	1,261	3,523	591
Chemicals and pharmaceuticals	49,203	70,185	41,259	5,138	5,246	3,938
Foundries and foundry supplies	17,005	27,144	6,305	21,323	17,399	7,193
Linoleum	3,066	2,754	2,703	44,541	29,458	21,746
Matches	95			2,965	2,953	2,453
Miscellaneous	42,573	65,556	40,917	3,427	3,752	2,362
Oils and greases	98,082	21,776	54,224	54,203	49,828	29,565
Paper and paper size	5,374	1,771	2,349	331,671	341,327	299,934
Paint and varnish	4,754,403	4,089,743	3,444,882	241,102	192,878	155,592
Printing ink	12,575	11,209	14,562	14,599	13,104	15,164
Sealing wax, pitch, insulations, and plastics	66,022	70,236	42,353	42,433	26,291	13,902
Shipyards, car shops	30,364	65,520	46,258	233	3 086	74
Shoe polish	617,449	527,838	555,046	735	610	587
Soap	3,260	10,539	5,700	225,867	218,967	239,869
Total	5,911,250	5,045,224	4,343,630	989,498	908,422	792,970

Bureau of Chemistry and Soils. From *United States Department of Agriculture Yearbook, 1933.*

Domestic production of turpentine for the years 1922–1927 averaged about 27,100,000 gallons per year. Exports run as high as 45 per cent of the annual production.

Annual production of rosin and wood rosin has in recent years varied from about 826,000,000 pounds to over 1,000,000,000 pounds.

USES OF TURPENTINE AND ROSIN

Turpentine is chiefly employed as a solvent in paints and varnishes. It mixes with and thins oils, resins, and oil-pigment mixtures and evaporates quickly when the film is spread. It also has some oxidizing, or drying, effect. Turpentine is likewise used in shoe polishes, in oils and greases, sealing waxes, and various other substances. It is the chemical basis of synthetic camphor (Chapter XIV).

Small quantities of specially purified turpentine are used in medicine.

Large quantities of rosin are used in the paper industry for sizing—imparting luster and weight and hindering absorption of ink or moisture. Rosin also enters paints and varnishes. A major use is in combination with alkalis in soap-making. Smaller quantities of rosin are distilled into rosin oils which are employed in lubrication. Sealing wax and linoleum also demand rosin. Quantities of turpentine and rosin used for various purposes in recent years are shown in Table II.

Other Resins

THE VARNISH RESINS

A considerable number of hard, translucent, and usually light-colored resins are used in varnishes and enamels. While these are quite similar in the physical characters to which they owe their value, they have widely different botanical sources and geographic origins. From any scientific standpoint, their nomenclature is almost hopelessly confused. Some of the most valuable are fossil resins, found in underground deposits on the sites of forests other evidences of whose existence have long since disappeared. "Copal" is a trade term which, while belonging rather specifically to some of these products, is sometimes used almost synonymously with "varnish resin." The principal grades of varnish resins are generally listed as kauri, dammar, and copal.

Kauri.—This is one of the few terms used to indicate a very specific type of varnish resin. Kauri is from *Agathis* (*Dammara*) *australis* of the Pinaceæ, the Kauri Pine (Fig. 111) of New Zealand. The tree is a huge one, rather broad-leaved, and of aspect considerably different from northern members of the Coniferæ. It still occurs in North Island, New Zealand, but the best quality and the principal supplies of resin are from fossil deposits. The resin is found in lumps a few feet below the ground surface. When located by probing with an iron rod, these are dug up, cleansed, and sorted for trade. Attempts to make the prospecting more rapid and efficient by going over the ground with dredges have not proved profitable. The color of kauri ranges from clear white to dark brown; the lightest and best is found in dry soil and the darkest in swamps.

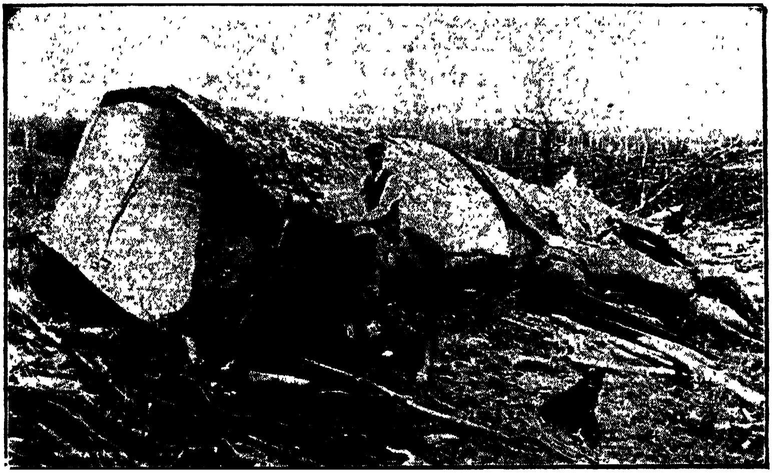

FIG. 111. — A Felled Tree of Kauri Pine (*Agathis australis*), North Island, New Zealand. (Photo by Jones and Coleman in Chamberlain, *Elements of Plant Science*, McGraw-Hill Book Company, Inc.)

More than half the kauri lands are Crown property; as the industry is an important one, the New Zealand government has strictly and beneficially regulated the exploitation of the deposits.

Kauri is one of the softer varnish resins. but the best grades are highly valued.

Dammar.—This term applies to a most miscellaneous group of resins, mostly originating in India and the East Indies. The principal dammars of commerce are from living trees of *Shorea* and other genera of the Dipterocarpaceæ of Malaya and the South Sea Islands. Centers of trade are the Dutch East Indies and Singapore.

Copal.—The true copals are from *Trachylobium* of the Leguminosæ. The hardest and best grade of varnish resin is Zanzibar or East African copal, from fossil remains in East Africa. Other copals, some from living trees and some from fossils, occur in West Africa and Belgian Congo. Manila copal, so-called—also known as elemi—comes from *Canarium* of the Burseraceæ. A minor group of South American copals is from leguminous trees related to *Trachylobium*.

Uses of Kauri, Dammar, and Copal.—With the exception of kauri, varnish resins are graded by hardness and by color—or rather by lack of it. Copals are heat-treated to drive off water and volatile oil and then employed with linseed or china-wood oil in making oil varnishes. Dammars, which are readily soluble in alcohol, wood alcohol, and turpentine, are used in spirit varnishes. Nearly colorless varnish resins are employed in enamel paints.

The recent development of cellulose lacquers (Chapter VII) has somewhat diminished the market for varnish resins.

Dragon's Blood.—This term is applied to a red, resinous substance from the fruits of *Calamus Draco* and other palms of Malaya and the Moluccas. The fruits of *Calamus Draco* are spheroidal, an inch or less in diameter, with a scaly surface upon which the resin exudes as they ripen. It is separated by beating the fruits in sacks. It is then boiled in water, kneaded, and molded into sticks or lumps for market. Dragon's blood is used chiefly for coloring varnishes and stains.

AMBER

This fossil resin is attributed to the extinct conifer, *Pinites succinifer*. It is of somewhat scattered distribution; the principal source is fossil beds along the shores of the Baltic Sea in East Prussia, where it is mined. Lumps of it are occasionally cast up by the waves. Amber occurs in irregular masses, usually small, but sometimes weighing several pounds. It is transparent or translucent, and varies in color from pale yellow to reddish or brownish. It is the hardest known resin and is principally used to-day for ornamental articles, such as pipestems, beads, etc. It was known and valued by the ancients; its property of attracting light objects when rubbed is supposed to have been discovered by the Greek philosopher, Thales of Miletus, in the first half of the sixth century B.C. This was probably the first artificially produced electrical phenomenon observed by man; the term ELECTRICITY is derived from the Greek *electrum*—amber. The ancients held amber in high regard and made from it charms and amulets. It is still used in the rites of the Mohammedan religion.

Amber was once used in varnishes, but partially because of its expense very little is so employed to-day. It is applied in the manufacture of some forms of artificial silk to render the finished article more elastic.

Lumps of amber sometimes enclose the bodies of insects of extinct species. These were embedded when the gum was soft and preserved by the antiseptic nature of the resin.

2. Tanning Materials

The Nature and Occurrence of Tannins

Tannins are a group of substances of wide distribution in the plant kingdom. Probably no green plant wholly lacks them; in many they are readily demonstrated, and in a considerable number they are sufficiently abundant to be of commercial value.

Chemically, tannins are far from simple. Most of them are glucosides of complex organic acids. They are amorphous, forming acid colloidal solutions in water. They are known and valued for a number of characteristic properties, particularly their formation of insoluble substances with certain classes of proteins. Through this action, skins of animals are tanned or converted into leather. A mild instance of protein-conversion is experienced in the astringent effect of tannin solutions in contact with the tongue or other mucous surface, or when tannin-bearing medicinals are employed to constrict and close small wounds and stop bleeding. Tannins form dark blue (*pyrogallol tannins*) and dark green (*catechol tannins*) compounds with iron salts; strong solutions of pyrogallol derivatives plus iron have afforded the most durable of inks since time immemorial. Tannins precipitate many metallic salts and some organic compounds, such as alkaloids; in these connections they are sometimes used in combating metallic and alkaloidal poisonings. In alkaline solution, they become oxidized in the air to a dark brown color; pyrogallic acid is used as a reducing agent in photographic development of films and plates.

PHYSIOLOGICAL SIGNIFICANCE OF TANNINS

Tannins are found in a wide variety of plant organs, particularly in green leaves and other plant parts where active metabolism is going on, but apparently they do not ordinarily serve as foods. They are likely to occur in quantity in barks and are probably concerned with the formation of cork. They are often found in unripe fruits, and the changes they undergo in the ripening processes have been presumptively connected with pigment formation. In some fruits at least, as the persimmon, their disappearance on ripening is more apparent than real; the walls of the tannin-containing cells become tough so that they are not readily broken when the fruit is eaten and consequently their astringent content escapes notice. To tannins have been attributed insect and fungus-repellant values. They are often secreted in quantity in wound tissue, being especially noticeable in the hypertrophied tissues of galls which result from insect-egg deposition and larval activity in the twigs of oaks and some other plants.

USES OF TANNINS

The dominant employment of tannins is in leather-tanning; save for this, they would scarcely be of sufficient importance to notice in an elementary treatise on plant economics.

The value of a tanning material is, of course, conditioned in large part by its tannin content, which varies from 4 per cent in low-yielding chestnut wood and oak bark to 70 per cent in nutgalls. Usually the tannin is concentrated by extraction and standardized. Different tannins vary somewhat in the qualities they impart to leather, and tanning extracts are often blended for use. Pyrogallol tannins produce a bloom, or slightly waxy appearance, on leather; catechol tannins do not.

The Principal Tanning Materials

Primitive tanning processes were discovered by most peoples at a comparatively early period of their culture, and tan-stuffs are widespread enough and abundant enough so that most corners of the earth have their own materials for leather-making.

The majority of commercial tanning materials are barks; a few very important ones are from wood. Leaves, roots, and one or two galls are also used.

Natural sources of tannin, particularly barks, are mostly bulky and of little value for unit of weight—factors which, until recently, tended to prevent their long-distance transportation. In early American tanning, New England led; to its supplies of hemlock bark were carried hides from the opening West and other distant sources. Boston became the leather center of the New World, and the shoes of Massachusetts cities trod the pavements and the open spaces of the world. As the New England hemlock supply declined, chestnut oak and chestnut of the southern Appalachians came into vogue. For foreign tanning materials, South American quebracho, mangrove bark from a wide tropical range, and sumac from southern Europe are largely imported, often in extract form. Some Oriental products, such as gambier and kino, are used both for tanning and dyeing.

HEMLOCK BARK

This staple of the American tanning industry is obtained from *Tsuga canadensis* of the Pinaceæ, a common forest tree found from Nova Scotia and New Brunswick southward through the Appalachians and westward to Minnesota. *T. heterophylla,* Western Hemlock, of the Western coast States, Canada, and Alaska, affords an enormous future supply which has scarcely been touched.

Hemlock, like other cambium-bearing trees, peels best in the spring. A peeling crew usually includes four men—one fitter, one spudder, and two log buckers. The lower ring of bark is removed before felling the tree. Two girdling cuts, four feet apart, are made by the fitter, after which the bark is split from ring to ring. With the spud, a tool somewhat resembling a huge long-handled chisel, the spudder pries off the bark, after which the tree is felled. The prostrate log is girdled at four-foot intervals, and the bark is removed with the spud. Bark-lengths are seasoned for a week or more by leaning them against trees, rocks, or the fallen log. They are then stacked. Tan-bark is usually sold by the cord—the equivalent of a pile four feet high, four feet wide, and eight feet long.

In the early days of the industry the rather inferior hemlock timber was usually left in the woods to rot, but in present practice, if the locality is at all accessible, it is utilized for lumber or pulp-wood.

Tanning extract is made by grinding the bark and leaching it with hot water. It is generally concentrated to a liquid with 25 per cent tannin content, but it may be fully dried.

From the first development of tanning in the Colonies, hemlock has been a principal American tan-stuff. It is now surpassed in amount by chestnut. Hemlock has been especially valued for sole and heavy leather and for sheepskins. It contains 8 to 10 per cent of catechol tannin and affords a firm, heavy, dark red leather. While oak-tanned leather has been generally preferred, tests indicate that for most purposes a hemlock product is superior. Hemlock is often used in combination with oak or with quebracho.

TANNING MATERIALS OF THE FAGACEÆ

The Fagaceæ, or Oak Family, includes several woody genera which are noted for their richness in tannin. Various members of it have long been utilized in the leather-making industries of both Europe and America. The genus *Quercus,* including the Oaks proper, is the largest group of the family, and its representatives with us are both numerous and widespread. Only a single American oak species, however, is of major tanning significance. The closely related *Lithocarpus*—Tanbark Oak—has

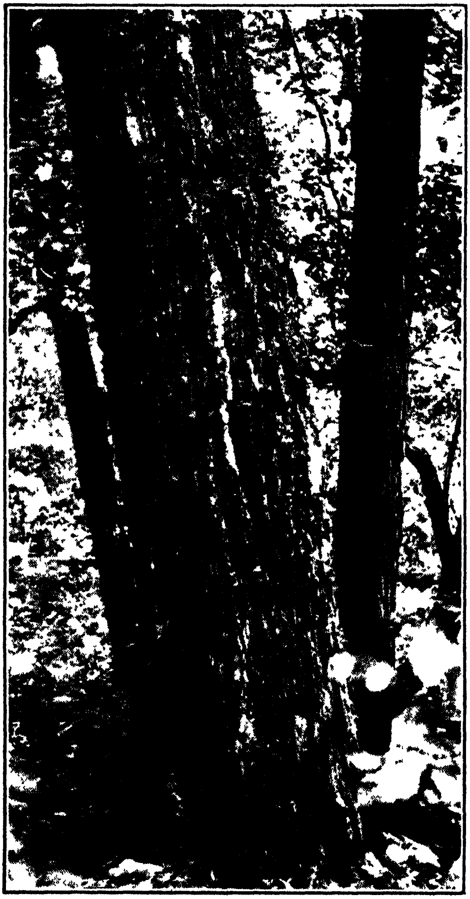

FIG. 112.—The Trunk of a Chestnut Oak (*Quercus Prinus*) in Tennessee. (Photo from United States Forest Service.)

recently assumed prominence, and *Castanea*, the Chestnut, is now our major domestic tan-stuff.

The Chestnut Oak.—Early American tanners utilized the barks of *Quercus alba*, the White Oak, and *Q. rubra*, the Red Oak; but for many years the dominant oak tan has been the bark of *Q. prinus*, the Chestnut Oak (Figs. 112, 113). This species is a large and vigorous forest tree, sometimes reaching 100 feet in height, with thick and deeply furrowed grayish or blackish bark. The chestnut oak is a tree of dry soils, rocky lands, and hill and mountainsides from Maine and Ontario to Kentucky, Tennessee, Georgia, and Alabama. The principal stands are in West Virginia and Kentucky. A large tanning industry has grown up about the chestnut oak in West Virginia and Virginia. It has been estimated that the present considerable supplies of bark will be exhausted about 1950. Large areas of chestnut oak are almost inaccessible to transportation. New supplies are, of course, developing; but reforestation with this species is slow.

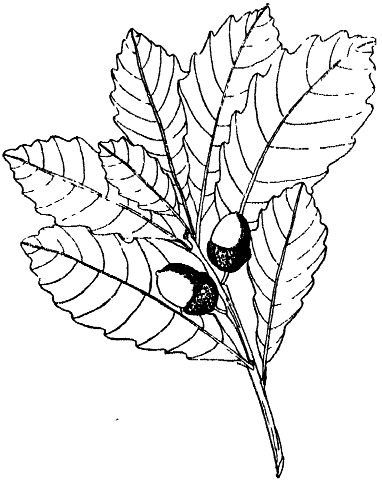

FIG. 113. — Chestnut Oak (*Quercus Prinus*). (E. Coffman.)

Chestnut oak bark is peeled between March and June, and air-dried for about six weeks in the woods. The timber is used to some extent for lumber, ties, and fuel. In tanning, both bark and extract are used. Oak bark is used particularly for sole and other heavy leathers. It contains 8 to 14 per cent of tannin in which both catechol and pyrogallol are probably represented.

Nutgalls.—Most species of oak are subject to the attack of small wasplike insects which deposit eggs in the rapidly growing tissue of twigs or leaves. The hatching and growth of the larvæ results in a remarkable stimulation or hypertrophy of growth and the production of a more or less globular excrescence known as a gall. These galls contain remarkably large quantities of tannin. American galls are common on many species of oak, but are so light in weight and so expensive of collection that they find no industrial use. Commercial nutgalls (Fig. 114), resulting from the growth within the twigs of the larvæ of *Cynips tinctoria* of the Hymenoptera, are from *Quercus infectoria* of Asia Minor. They somewhat resemble small brown or grayish tuberculate marbles. They are extremely heavy for woody growths, sinking readily in water. They contain 50 to 70 per cent of pyrogallol tannin, and 2 to 4 per cent of gallic acid. Their reacting properties with iron salts have been known for ages and have been utilized in the production of inks whose lasting powers are still unsurpassed. Nutgalls have some claim to the title of the earliest known chemical reagent. They are employed at present in the manufacture of inks, tannic acid, pyrogallic acid, and allied chemicals.

On several species of *Rhus* (Sumac) galls of most irregular shape are formed in a similar manner. These also are rich in tannin. *Rhus* galls collected in China and Japan are used, like nutgalls, in the manufacture of tannic and gallic acids.

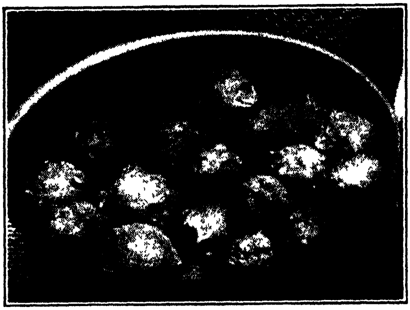

FIG. 114. — Nutgalls. (Courtesy Fisher Scientific Co.)

Valonia.—An interesting tan-product is valonia, the acorn cups of *Quercus ægilops* (Fig. 115) and probably other species, of Smyrna, Greece, and Asia Minor. Valonia oak has been introduced for reforestation in Algeria. The ripe acorns are shaken from the trees, dried on the ground, and fermented in heaps for several weeks, during which time the acorns contract and separate from the cups. The acorns contain little tannin, and are fed to hogs. The best Greek valonia is from unripe acorns. The total valonia harvest runs from 50,000 to 70,000 tons per year. Valonia is very rich in a mixture of catechol and pyrogallol tannins; the cups proper contain 30 to 40 per cent and their hairy linings, the beards, contain about 10 per cent more than the cups. Valonia is used for tanning high-grade light-colored leathers; alone, it yields a brittle product and is commonly combined with other tans.

The Tanbark Oak.--Lithocarpus densiflora (Fig. 116) ranges from southern Oregon through the northern and central Coast Ranges of California. Its principal development is nearly coincident with that of the redwood. It varies from a spreading shrub to a forest tree 40 to 100 or even 150 feet in height. The characters of the species combine those of oak and chestnut. The fruit, for example, is a typical acorn; but the cup suggests the burlike character of the chestnut involucre. The general habit is oaklike,

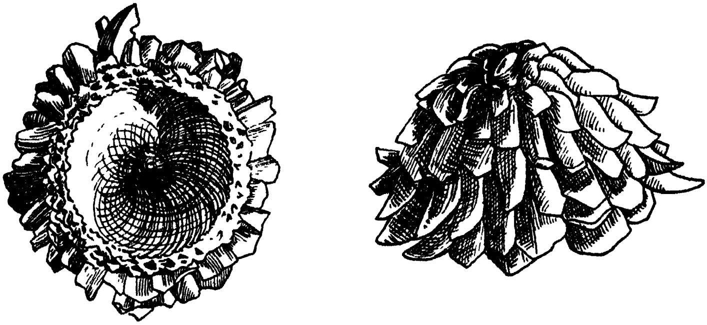

FIG. 115. — Acorn Cups of the Valonia Oak (*Quercus ægilops*). (E. Coffman.)

but the rather thick, whitish-tomentose leaves are shaped and veined in resemblance of the chestnut. The brown, much-fissured bark is from three-quarter inch to three inches in thickness; old trees sometimes exceed even this. The wood lacks the valuable tannin-characters of the chestnut; it is close-grained, hard, strong, and valuable. Because of the steepness of the mountainsides of its principal range it is difficult to get the heavy logs to mill, and much of a potentially valuable timber is allowed to waste after peeling.

Nearly all the peeling of tanbark oak (Fig. 117) is in California.

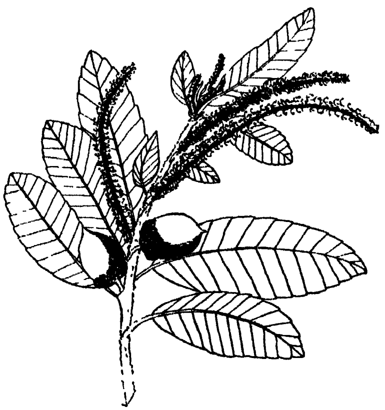

FIG. 116. — Tanbark Oak (*Lithocarpus densiflora*). (E. Coffman.)

Tanbark oak and redwood occur together, and in a clearing operation the former is generally removed first. Most of the peeling is done between mid-May and August. As in the case of the eastern barks, the lower four feet of bark is removed from the standing tree; after felling, further lengths are peeled as high as the thickness reaches half an inch. Small trees are barked to a height of eight or ten feet without felling. This practice is called "jayhawking."

Tanbark oak is the mainstay of a considerable Pacific Coast tanning industry, and small supplies are shipped to the Orient. It has been estimated that the present supply should last till 1950 or 1960. The tree reproduces abundantly from sprouts and also yields large quantities of acorns; the regions where it occurs are adapted to nothing but forest growth, and with reasonable management should yield for a long time to come.

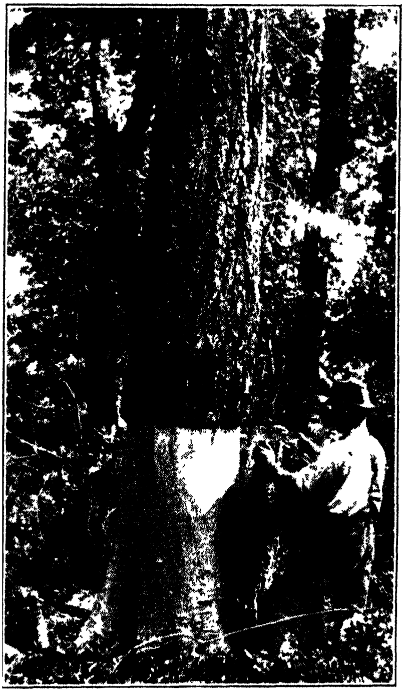

Fig. 117. — Removing the Lower Portion, or "Shin" of Tanbark Oak Bark. (Copyright by A. O. Carpenter. Courtesy of United States Forest Service.)

Tanbark oak bark is exceptionally high in tannin, yielding from 10 to 29 per cent of catechol tannin. It is valued for heavy leathers, such as are used for soles, harnesses, and straps.

Chestnut and Chestnut Extract. — The American Chestnut (*Castanea dentata*) (Fig. 118) is one of the largest and best-known trees of the eastern forest from Maine and Ontario southward through the Appalachians to northern Georgia and Florida. It is particularly abundant in the highlands of the Southern States, where its future prospects have been ruined by the chestnut blight (Fig. 119). The main importance of the chestnut has been as source of ties, poles, and cheap lumber. The rather coarse-grained yellowish brown wood contains from 4 to 10 per cent of catechol tannin and affords about 50 per cent of the tanning material produced in this country.

Chestnut is used for tanning in the form of the extract. This is mainly prepared in the southern Appalachians where the great stands of the chestnut are concentrated. Southern chestnut also contains a higher tannin-percentage than the northern tree.

In preparation for extraction the wood is ground and crushed into chips in machines called "hogs," of which there are a number of kinds. The chips are repeatedly extracted with hot weak tannin-liquor in huge wooden tanks. This liquor passes from tank to tank, becoming constantly more concentrated, and is at length filtered and evaporated to the desired concentration. Liquid extracts run from 25 to 35 per cent tannin; a dried extract yields 60 to 70 per cent. In some mills the exhausted chips are worked into coarse paper or fiber board. Some plants operate in connection with tanneries. In 1930 there were twenty-one extract plants located in the southern Appalachians, some of them large and highly mechanized establishments capitalized at $1,000,000 or more (Fig. 120). Even at the present rate of consumption, existing chestnut supplies would last a century at least, could they by some miracle be preserved from deterioration. As chestnut naturally reproduces abundantly by sprouting, a perpetual supply would be assured could the chestnut blight be exterminated by another miracle. Under actual conditions, however, the percentage of fatally infected chestnut is very high; sprouts are attacked as soon as they appear; and the end of the species as a commercial crop seems already in sight. Experiments indicate that dead and standing chestnut loses its tannin content but slowly; it has deteriorated only slightly in trees which have been dead twenty-five to thirty years. Roots of dead trees, however, rot in the soil; and windfall takes place sooner or later, after which decay and insect damage are promoted by the moisture of ground contact of the trunks. Presumably the chestnut extract industry may maintain itself for a decade or two. Meanwhile, attempts are being continued to locate in Asia and establish in America desirable

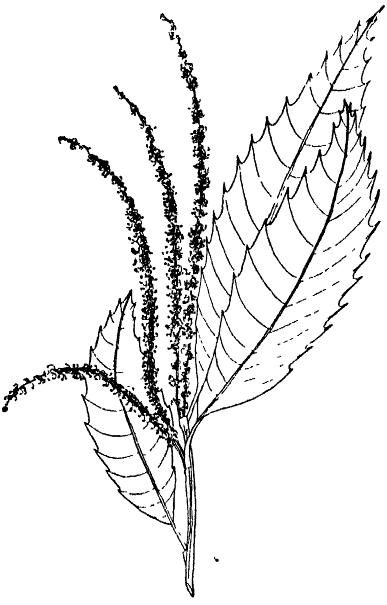

FIG. 118. — Chestnut (*Castanea dentata*), Leaves and Staminate Catkins. (E. Coffman.)

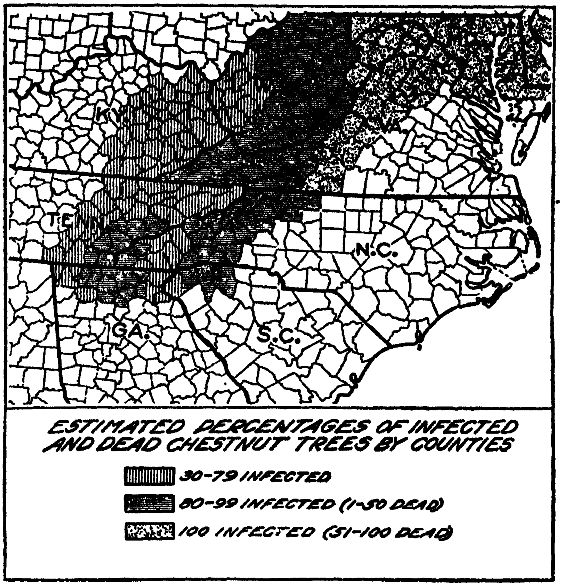
KY.
TEN
VA.
N.C.
GA.
S.C.
ESTIMATED PERCENTAGES OF INFECTED AND DEAD CHESTNUT TREES BY COUNTIES
30-79 INFECTED
80-99 INFECTED (1-50 DEAD)
100 INFECTED (51-100 DEAD)

FIG. 119. — Estimated Distribution of Chestnut Blight. This affected the more important chestnut counties of the southern Appalachians in December, 1929. Each year the degrees of infection and killing increase. (Bureau of Plant Industry.)

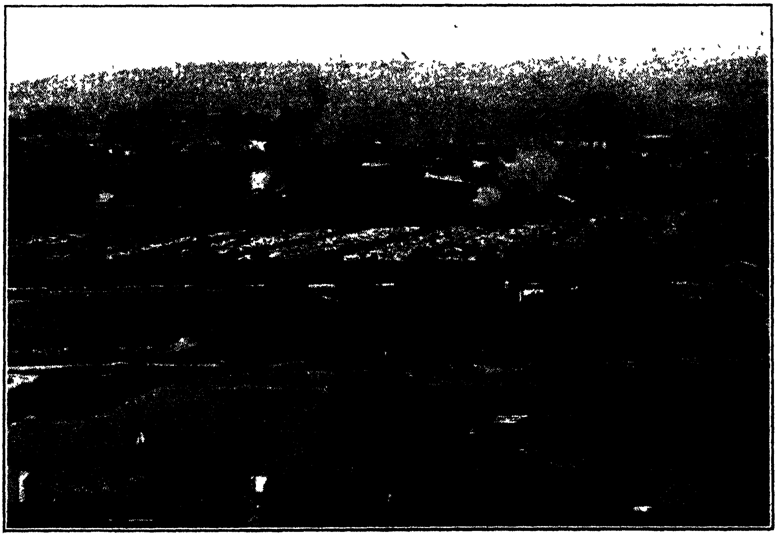

FIG. 120. — A Chestnut Extract Plant at Buena Vista, Virginia. (Photo from United States Forest Service.)

strains of the more resistant Asiatic chestnut. Whether such reforestation can ever replace the disappearing *Castanea dentata* is problematical.

Chestnut extract is used in the tanning of sole leather, harness leather, belting, and other heavy leathers. It is considerably used in combination with quebracho. It also serves as a weighting agent and mordant in the dyeing of blacks on silk.

CERTAIN FOREIGN TANNING MATERIALS

At present about one third of the organic tanning materials used in this country are of foreign origin. The development of this considerable trade has taken place mainly since 1900, as our native tans have become scarcer and higher in price. Nevertheless, of the very large number of tanning materials found elsewhere in the world, comparatively few are imported in significant quantities. These are mainly cheap products of high tannin content. Of foreign tanning materials, nutgalls and valonia have already been noticed. Others are quebracho, mangrove, wattle, myrobalans, divi-divi, sumac, and gambier.

Quebracho.—The term QUEBRACHO is of Spanish origin, signifying "axe-breaker"; it is applied to several very hard-wooded South American trees. Of chief importance is the *Quebracho colorado* (Fig. 121), cited botanically as *Aspidosperma Quebracho-colorado* or *A. colorado,* of the Apocynaceæ. It is a small and slow-growing tree of northern Argentina and Paraguay, where it is the principal species of a large area of ancient forest irregularly interrupted by grasslands. The heartwood of quebracho is extremely heavy, weighing about 78 pounds per cubic foot and containing 20 to 28 per cent of catechol tannin—a relatively enormous amount for a lignified region. Chestnut and quebracho, in fact, are the only species whose wood is exploited to any important extent as a tannin-source.

Considerable quantities of quebracho wood are shipped from South America to Europe and the United States for extraction, but large and well-equipped factories are now located in the producing countries, in a region which knows no other important manufacturing enterprise. The heavy, dark red heartwood is chipped and extracted by boiling; the result is a liquid extract of about 35 per cent tannin content or a solid extract averaging 65 per cent. Because of economy in transportation, the latter predominates.

Of all tanning extracts used in the United States in 1925, quebracho constituted 40 per cent and chestnut slightly less.

Quebracho is a relatively cheap, quick-acting tan. It is employed for all classes of leathers, but particularly for some kinds of light leathers. In combination with hemlock or oak it is used for bag, patent, and automobile leathers; for sole leathers and other heavy goods.

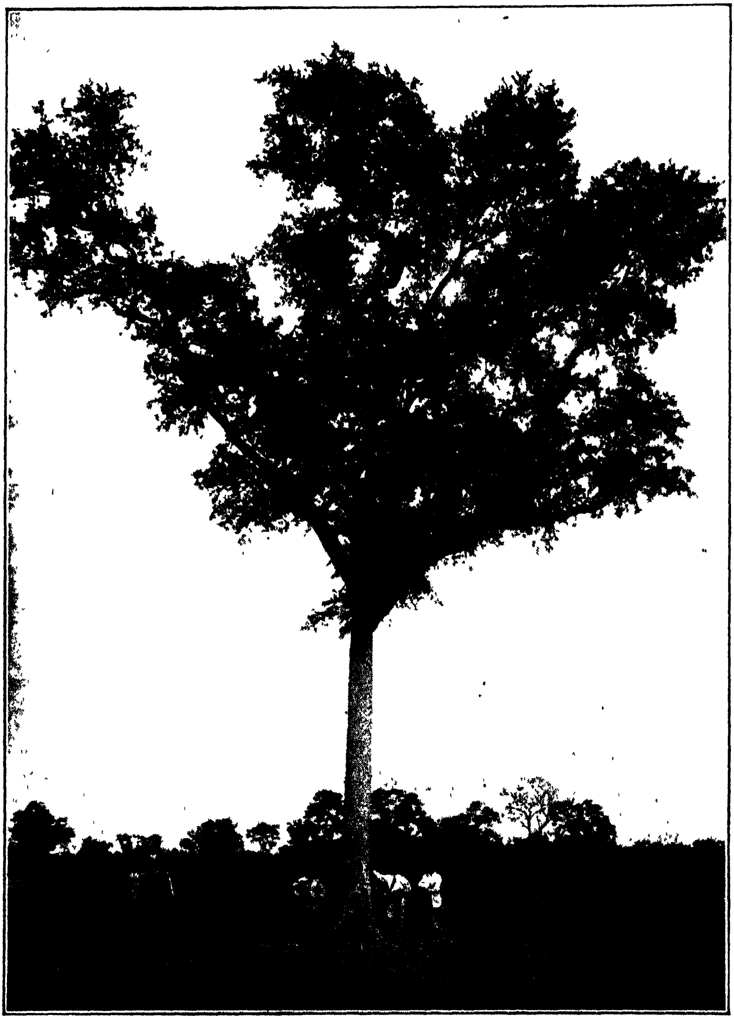

FIG. 121. — An Exceptional *Quebracho Colorado* yielding five tons of wood. (From the *Journal of the American Leather Chemists Association*)

Mangrove.—*Rhizophora Mangle,* the Mangrove, is a most characteristic and widespread tree of tidal lands of South America, Africa, Madagascar, and the East Indies. Its thick, heavy bark yields a very variable amount of catechol tannin, from as little as 5 per cent to as high as 45 per cent. Old trees are said to produce the most. The bark is an important tan in South America, and its extract is rapidly coming into wider use in the United States. The peculiar nature of the mangrove swamp, with its tidal variations and the arching tangles of its prop roots, renders cutting difficult. In Brazil, the leaves of mangrove are used in tanning.

A small quantity of mangrove bark is peeled in Florida.

The very widespread genus *Rhizophora* is said to constitute the greatest source of tanning supplies for the future requirements of the world. Besides *Rhizophora Mangle* a number of other representatives of the family—Rhizophoraceæ—are of tanning value.

Mangrove is a very cheap tan, generally used in combination. Its extract also has limited use in dyeing browns on cotton.

Wattle.—The Wattles are species of *Acacia* of South Africa, Australia, and Tasmania. Wattle bark is generally imported in the form of extract. Use of wattle in the United States is of recent development and probably will increase in importance.

Myrobalans.—Myrobalans are the dried fruit of *Terminalia Chebula* (Fig. 122) and other species of *Terminalia,* of the Combretaceæ, Indian forest trees. The fruits are about an inch in length and resemble dried plums; their tannin content is chiefly in the pericarp. The forests of *Terminalia* are under British governmental control and collection is carefully regulated. The fruit is dried on the ground with considerable care, since its value is spoiled by rain-wetting. There are several varieties, differing somewhat in tannin content, color, and value; the lightest colors are valued highest. Content ranges from 30 to 40 per cent of pyrogallol tannin.

As a tan, myrobalans are blended with other materials and used for a considerable variety of leathers. They also have limited use in dyeing blacks, as dyeing mordant in fixing colors, and in ink-making.

✓*Divi-divi.*—Divi-divi is the pods of *Cæsalpinea Coriaria* (Fig. 123) of the Leguminosæ, chiefly collected in Venezuela and Curaçao. They contain 40 to 45 per cent of pyrogallol tannin and are used in blend with myrobalans, quebracho, mangrove, and other materials. Although divi-divi supplies are abundant, accessible, and also cheap, their use in the United States is not extensive. They are much used in Germany.

Sumac.—The sumac of commerce is chiefly the dried leaves and twigs of *Rhus Coriaria* of the Anacardiaceæ. One of the very few tan-stuffs cultivated, it is produced on a rather extensive scale in Sicily and southern Italy. Leaves of American species of *Rhus* also run high in tannin content and are collected to some extent in the Appalachians. Species used are *R. glabra*, *R. copallina*, and *R. hirta*, all abundant shrubs of hillsides and valleys but expensive of collection under American conditions.

Sicilian sumac contains 20 to 35 per cent of pyrogallol tannin and is used mainly for tanning, though to some extent for dyeing. As a tan, it is employed for the fine light-colored leathers used in bookbinding, glove-making, etc. American sumac finds employment as a mordant in dyeing and printing cotton and silk.

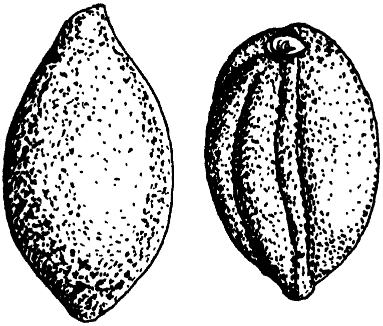

FIG. 122. — Myrobalans (*Terminalia chebula*). (E. Coffman.)

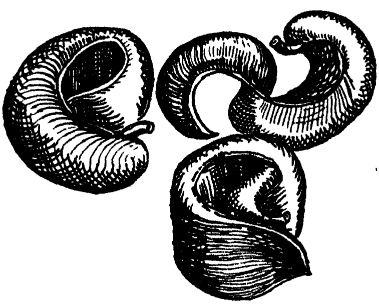

FIG. 123. — Divi-divi (*Caesalpinia Coriaria*). (E. Coffman.)

Gambier.—Gambier is the dried extract of the leaves and twigs of *Ouroupária Gambir* of the Rubiaceæ. This climbing shrub is native to southern Asia and the South Sea Islands. It has come into cultivation in Malaya under the encouragement of British governmental authorities. The twigs and leaves are extracted with boiling water and the product evaporated, stirred, hardened, and cut into cubical blocks. It contains 35 to 40 per cent of pyrogallol tannin.

Gambier is a material of many uses. As a tan it is employed in connection with sumac for calfskins and sheepskins, horsehides, rabbit skins, etc. It is rapidly penetrating and is generally blended with oak or hemlock when used for heavy leathers. It is employed as a mordant in tanning and as a brown dyestuff. Gambier is an ingredient of boiler compounds for the prevention of scale formation.

It is also a minor astringent in medicine.

3. Cork

In a preceding chapter brief attention has been devoted to the nature and structure of cork. It has been pointed out that the outer region of bark of most of our common trees is made up of a fairly well-defined periderm, whose most bulky portion is a phellem or cork layer, made up of suberized cells. This is somewhat brittle and inelastic in most plants, but decidedly tough and

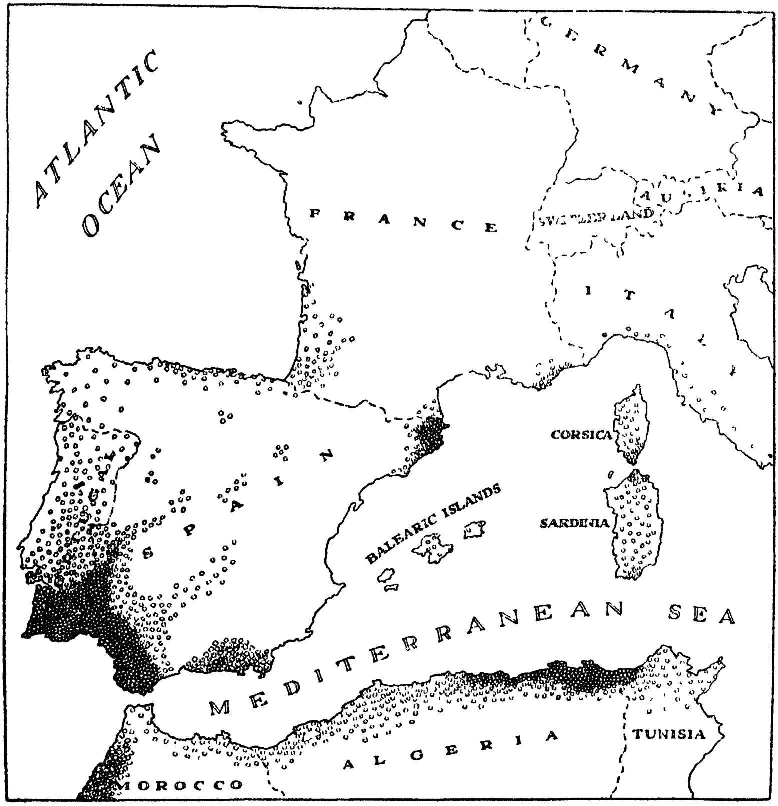

FIG. 124. — The Range of the Cork Oak in Western Europe and Northern Africa. Comparative density of the cork forests is shown by the use of the symbol O. The darkly shaded areas indicate dense growth and are the most important sources of supply. (Courtesy of Armstrong Cork Co.)

resilient in the Cork Oak, *Quercus Suber*. Commercial cork, in fact, is a unique substance, with a complex of characteristics which make it indispensable for a multiplicity of uses in our present civilization. Cork bottle-stoppers and floats were known to the Romans and perhaps to their predecessors. The application of frictional characters and acoustic properties of cork have been capable of development only by modern research.

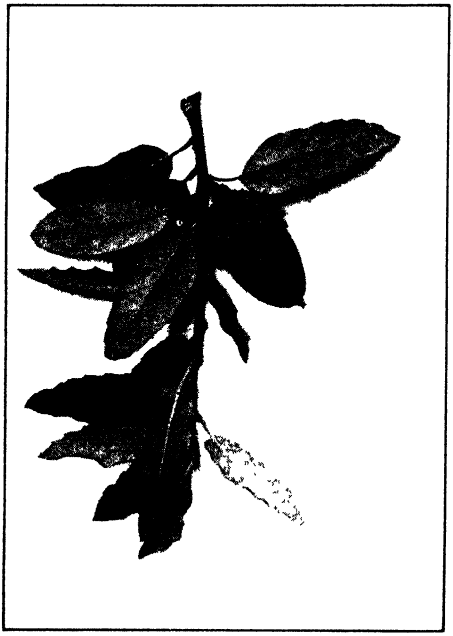

FIG. 125. — Leaves and Acorn of the Cork Oak (*Quercus Suber*).

The Cork Oak and Its Products

Quercus Suber is a small to medium-sized, rarely large, evergreen oak which in general habit resembles the Coast Live Oak, *Q. agrifolia*, of California. Its habitat is the Iberian Peninsula and the countries bordering the Mediterranean Sea (Fig. 124). It has been introduced as an ornamental in the warmer States of America and is becoming popular in California.

The height of *Quercus Suber* rarely exceeds sixty feet; the diameter, four feet. It occurs in semi-cultivation and in rather scattered and mixed forests; like most oaks with sufficient opportunity, it is short-trunked and deliquescent into several large branches. The leaves (Fig. 125) are one and one-half to two inches long and an inch or less in width, sparse, and slightly sharp-serrate; they are dull green above and whitish below. The acorns are about an inch in length; they are eagerly eaten by

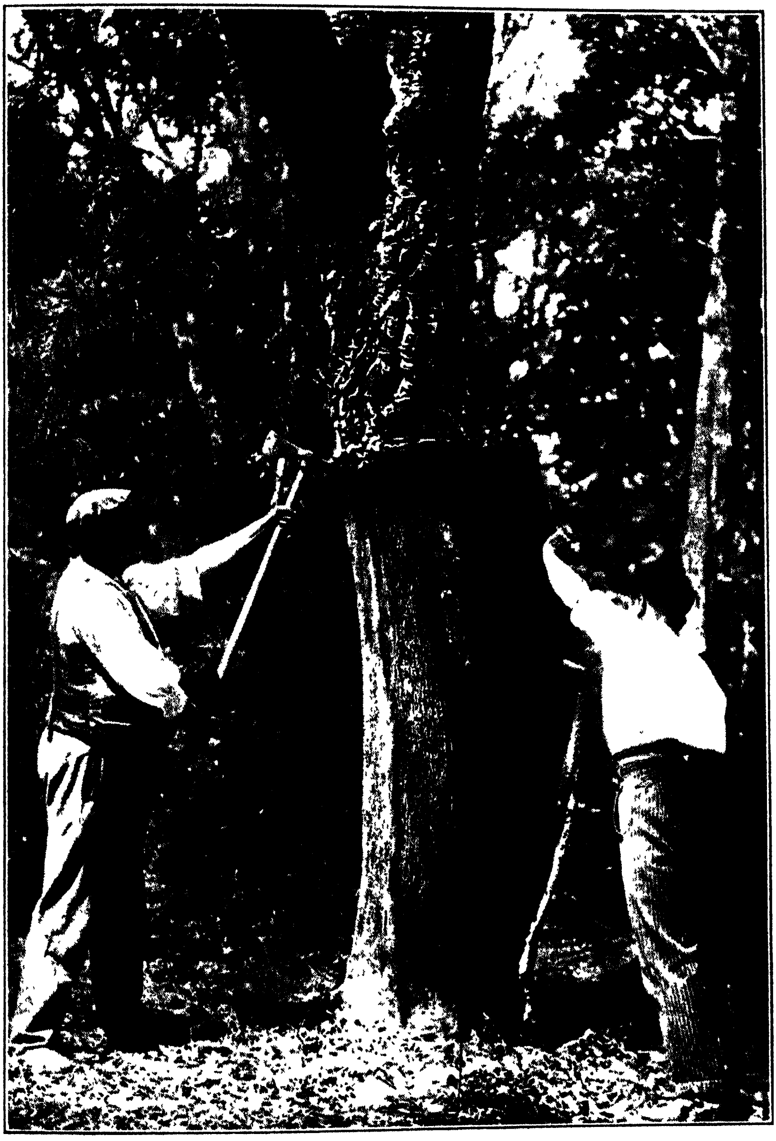

Fig. 126. — Stripping the Bark from the Cork Oak. (Courtesy of Armstrong Cork Co.)

swine, which root through and destroy the underbrush of cork forests, incidentally reducing the fire-hazard. Forest owners are paid for the acorn crop on the basis of weight gained by the swine. Hams made from swine fed on cork oak mast are said to have a peculiarly piquant flavor.

THE COLLECTION OF CORK

The first-formed cork of the oak is rough, deeply furrowed, and of little value. This, the virgin cork, is generally removed when the trees reach a diameter of about five inches, at the age of about twenty years. It is used for tanning, or coarsely ground for the "ground cork" used in shipping Spanish grapes, or employed in cork composition products.

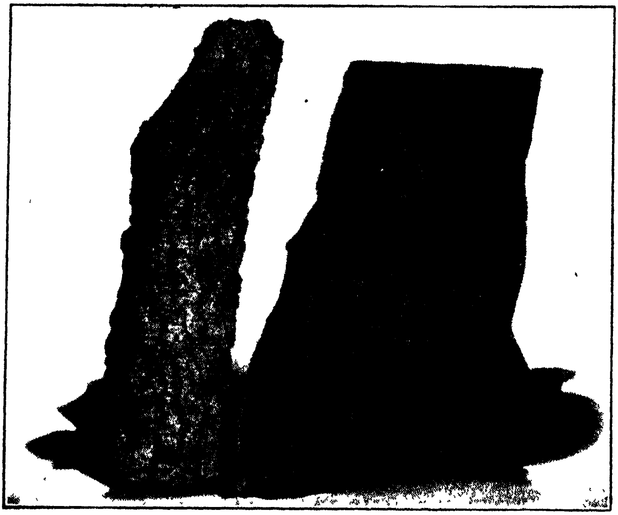

FIG. 127. — Cork as It Comes from the Tree. The piece on the left is virgin cork, good only for grinding. (Courtesy of Armstrong Cork Co.)

If cork is removed carefully, a new phellogen forms, and a second crop is available in eight to ten years. Subsequent crops may be had at similar intervals, indefinitely. In Portugal and French North African possessions the collection and commerce in cork is regulated by the government in the interest of conservation. Stripping is done in June or July; periods of hot-dry winds are avoided because of the danger of desiccation of the uncovered cork-cambial regions.

Cork is air-seasoned for a time after stripping and then boiled. The boiling removes a portion of the tannin, softens the broken outer layers, and facilitates pressing and baling. After boiling, the rough outer portions are scraped off; the remainder is flattened and dried and sent for further processing to local manufacturing and processing centers. There it is sorted, trimmed, and manufactured or shipped. In European usage there are about twenty-five grades of cork, which become as many as eighty under American sorting. The best cork is from trees which have been several times stripped, and often it is from the larger limbs rather than the trunk.

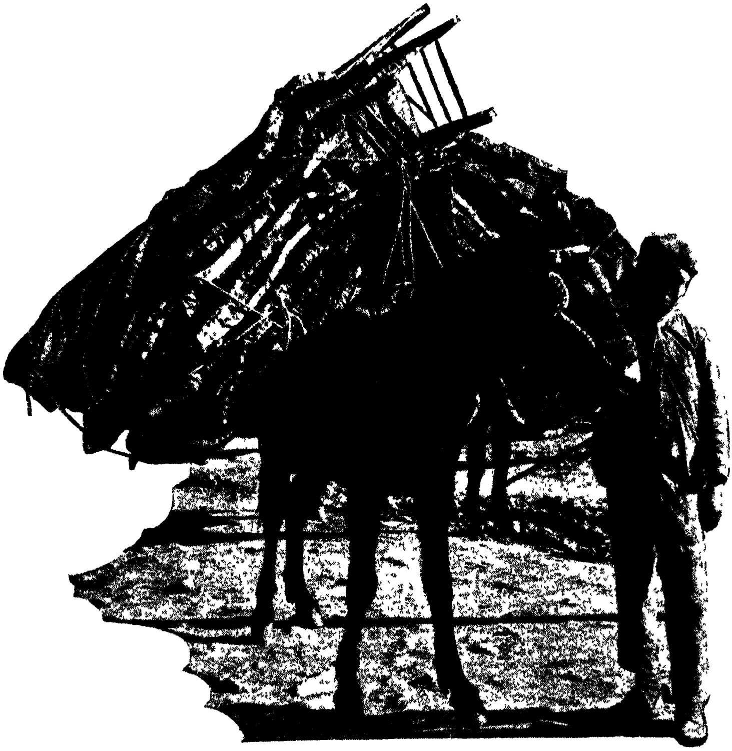

FIG. 128. — Fifty-three Per Cent of the Burro's Load is Air. (Courtesy of Armstrong Cork Co.)

THE NATURE OF CORK

The valuable and characteristic properties of cork are enumerated as follows by a large American cork manufacturing firm:[1] (1) Buoyancy and light weight; (2) cellular structure; (3) resilience and compressibility; (4) high resistance to deterioration; (5) resistance to moisture and common liquids; (6) high resistance to the passage of heat; (7) ability to absorb sound and vibration; (8) high coefficient of friction. These properties are most readily understood through a consideration of the cellular structure of cork.

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[1] Armstrong Cork Company, from several of whose publications much of the material here included is derived.

The Cellular Structure of Cork.—To cork we owe the first microscopically gained conception of plant structure. The initial observations of Hooke, published in 1665, show and describe the make-up of cork quite clearly. The cells are thin-walled, laid down very regularly by the phellogen. They present rectangular figures in cross- and radial-section and polygonal ones in the tangential aspect (Fig. 129). From any single microscopic view they appear of very simple form and association, but it has been computed that the average cork cell lies in contact with and is more or less compressed by fourteen others. The walls are thin, initially of cellulose which quickly becomes infiltrated by a very complex and moisture-proof substance called suberin. The protoplasts, cut off from outside moisture, soon die, and only dried remnants are left. Fifty-three per cent of total cork volume is cell cavity; in other words, air space. Throughout the phellem region are rather numerous lenticels, through which respiratory and moisture exchanges in living inner bark cells are made possible. Liquid from the lenticel, however, does not enter the cork cell,

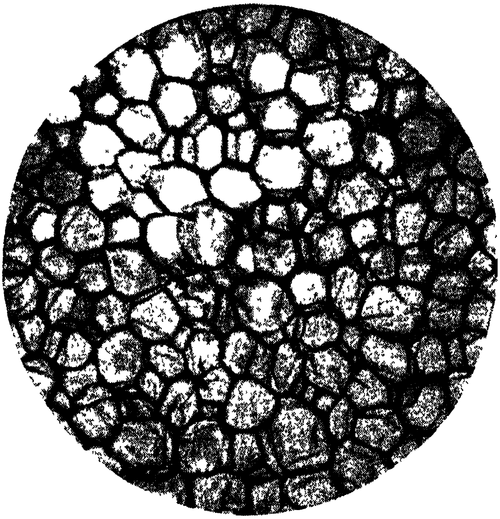

FIG. 129. — Photomicrograph of Cork, Tangential View. (Courtesy of Armstrong Cork Co.)

nor does air in the cell escape through cell wall or lenticel (Fig. 130). In the manufacture of bottle-stoppers leakage is avoided by orienting the corks with lenticels crosswise. The small amount of actual cork substance per unit of volume explains the lightness of cork; and the impenetrability of its walls, its buoyancy. Compression of cork results in the compression of the air-content of each cell; this air, unable to escape, tends to return to its original volume when the pressure is released. Thus the cork, whose thin walls are easily compressed, is extremely resilient. Corks thrust tightly into bottles for years spring back almost to their original volume when removed. The tiny air-filled prismoids conduct temperature-change but slowly; sound and other vibrations pass with difficulty and are scarcely reflected at all. Chemical character of the suberin and also, probably, its ultramicroscopic structure, impart to a cut-cork surface an apparent velvety smoothness which is curiously combined with a very considerable quality of friction, the latter enhanced by the myriad microscopically rough edges of broken cells. The material of the pectic intercellular layer acts as adhesive when ground cork is heated and pressed.

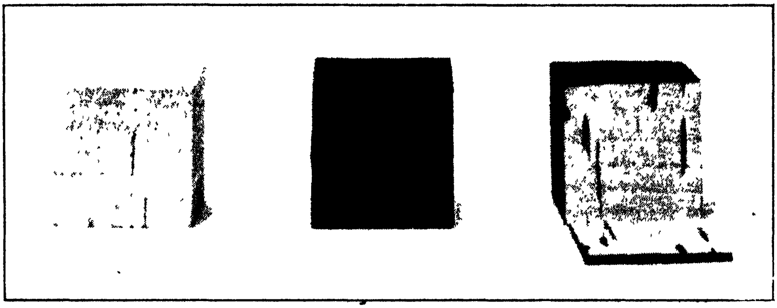

FIG. 130. — A Block of Natural Cork Was Boiled for Twenty-four Hours in an Alcoholic Solution of Nigrosine Dye. *Left*, before, *center*, after; *right*, cross-section showing penetration of the dye in lenticels only and not through cells. (Courtesy of Armstrong Cork Co.)

THE USES OF CORK

Many uses of cork come immediately to mind without effort. Corks, once cut by hand and now made by machinery, still are a very important commodity. Millions of corks for the great European wine industry are made in Spain, and in them are utilized the very finest grades of cork bark, or "corkwood," as the raw material is called. In the manufacture of corks, the disks are first punched as cylinders; they are tapered by a separate operation. A little reflection will indicate the mechanical difficulties which prevent the punching of tapered corks in one process. Strong acids corrode cork; alkalies destroy it more slowly; but, for most purposes and most liquids, cork stoppers are unsurpassed, despite numerous efforts to fabricate a substitute.

Among other objects made of natural cork are floats—not only the small "bobbers" used on fishing lines, but larger ones used for seines and other nets. It is used for life-preservers; handles for various objects; shoe-insoles; cork balls of all sizes, including centers for baseballs and tiny pea-sized ones whose vibration lends the bubbling trill to the referee's whistle. It appears as split cork for cork helmets, musical instruments, and cork paper; thin-shaved, for cigarette tips and for use in the making of novelties.

Among the most recent and notable developments of cork, many make use of granulated cork, cemented by the adhesiveness of its own intercellular layers plus an artificial binder, and pressed and formed to any desired shape. By these means the natural limitations of the size of corkwood sheets are overcome. Thus are made flooring-blocks and tiles; insulations for electric refrigerators and refrigeration piping, for walls and roofs of residences and public buildings; also gaskets for machinery, friction-faces on textile winding spools and other machinery, and blocks for placing under operating machinery to reduce transmission of vibration to building-structure. Cork is used, too, for hundreds of other articles, some familiar, others rarely seen outside their special and limited applications. In these granulated products are used the waste that accumulates in the making of bottle-corks and other whole-cork articles in this country. In many recent years, imports of cork waste, shavings, and refuse have exceeded in quantity amounts of ordinary corkwood brought into this country.

Linoleum.—One of the principal cork uses of the present day is in linoleum manufacture. This common and well-known floor covering had its beginning in the 1860's in the observation of the English inventor, Walton, that the surface of linseed oil exposed to the air oxidized to a gummy, rubbery film. Linoleum is essentially a mixture of oxidized linseed oil, finely ground cork, and smaller quantities of rosin, gums, and other ingredients deposited on a burlap backing and inlaid or printed with colors and designs.

COMMERCE IN CORK

Trade in corkwood and cork waste centers in Portugal and Spain. Portugal supplies about 50 per cent of American imports, Spain 30 per cent, and Algeria and Tunis about 15 per cent. The largest imports of recent years were those of 1926, when 126,000,000 pounds of corkwood and 179,000,000 pounds of cork waste were entered. Spain is the principal center of European cork manufacture. The United States imports relatively small quantities of cork manufactures, the largest item being cork insulation.

CHAPTER VI

FOREST PRODUCTS: RUBBER AND OTHER LATEX PRODUCTS

1. LATEX

The Nature and Occurrence of Latex

In a previous chapter, reference has been made to the occurrence in many plant families of a white or sometimes colored emulsion, complex in character and known as LATEX. Latices of various plants differ rather widely in their composition. A watery liquid, or serum, holds in suspension microscopic globules of hydrocarbons, resins, gums, etc., and often granules of starch and protein. In that of the opium poppy, morphine and other alkaloids are found. Upon exposure to the air, latices usually separate somewhat, or coagulate, and generally become darker in color. These changes are probably due in part at least to the action of oxidizing enzymes. The latex of *Carica* contains a proteolytic enzyme, papain, of which some therapeutic use has been made.

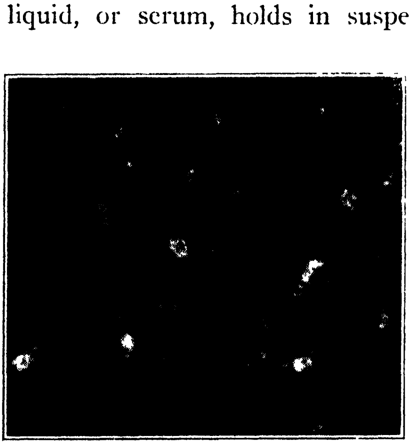
FIG. 131. — A Diluted Latex, Highly Magnified, Showing Rubber Suspensoids. (Courtesy of F. E. Lloyd.)

Of all latices, those yielding rubber are of the greatest significance to the human race. The rubber-yielding substance occurs in spherical or pear-shaped globules of varying size (Fig. 131), ranging in *Hevea brasiliensis*, the principal commercial rubber source, from 0.5 to 2 microns in diameter. Upon exposure to the air, or by treatment with smoke of certain chemicals, these globules coagulate and become rubber, a hydrocarbon to which the formula $C_{10}H_{16}$ is assigned.

Rubber-yielding latices are numerous, but commercial rubber at present is drawn from very few plants. These are chiefly tropical trees or vines which afford it in quantity, relatively free from deleterious mixture with resins and other undesirable substances. While until very recent time rubber was a product of the natural forest, modern production centers on species which can be grown and continually cropped on large plantations located in the tropics, where abundant supplies of cheap and fairly efficient labor are available. Only the plantation, in fact, has made the modern rubber-using industries possible.

Among other latex products of some technical importance are jelutong, gutta-percha, balata, and chicle. Of these, only gutta-percha is cultivated; the others are still from tropical forests.

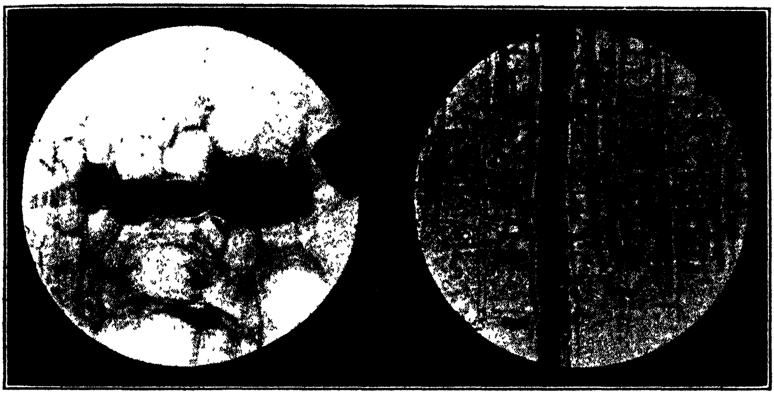

FIG. 132. — Latex Vessels in Cortex of *Hevea*. *Left*, cross-section; *right*, radial-section, highly magnified. (Courtesy of F. E. Lloyd.)

Latex-Bearing Tissues

Laticiferous ducts are of two sorts: latex vessels and latex cells. These are often similar in appearance, but they differ in their origin. Latex vessels, such as those of *Hevea* (Fig. 132), the principal rubber plant of the present day, are formed by the fusion of many meristematic cells through solution of their end-walls. Outgrowths of adjacent tubes join and anastomose. Latex cells, found in *Euphorbia* and some other genera, are single cells which originate in the embryo and proceed to grow with and throughout the developing plant much as does the mycelium of a parasitic fungus—and without anastomosing.

Latex components may also occur outside definitely laticiferous tissues. In some members of the Compositæ, such as Goldenrod (*Solidago*) and Guayule (*Parthenium*), rubber is found in solid or semi-solid form in certain cells.

Laticiferous tissues occur most commonly in the barks of dicotyledonous plants, and the product is usually obtained by incising the cortical region and collecting the exudate. Latex also occurs in leaves, and occasionally, as in *Ficus,* in the pith as well as in the bark.

No vital rôle for latex has been established. Injury which may attend its removal is to be attributed to wound effect rather than to the loss of the latex itself. As latex commonly coagulates on a wound and seals it to some extent, it is presumably of some value in preventing the drying of tissue and in hindering the entrance of fungi and insects.

2. RUBBER

History of Rubber

Rubber is of widespread occurrence in many plants—mostly tropical—of both hemispheres, but the development of its use by mankind is very recent. Natives of the West Indies, Mexico, Central and South America were probably first to gain some limited knowledge of the product and its properties. School-book histories of America tell how Columbus brought back from Haiti bouncing balls of rubber, which he found there in use in some primitive game. Later, Portuguese explorers of Brazil found Amazonian natives waterproofing shoes with rubber, and other explorers observed Mexicans chewing it out of the guayule shrub. The European discovery of *Hevea brasiliensis* is attributed to La Condamine and other French explorers of South America about the middle of the eighteenth century. The word CAOUTCHOUC, by which the substance was long known, is a French rendition of the Indian *cahuchu.* The English term RUBBER came from the use of caoutchouc in erasing pencil-marks—a discovery of the English chemist, Priestley, in 1770. The first attempts at commercial waterproofing were made in Brazil, as an outgrowth, probably of ancient Indian practice. Rubber utilization was later taken up in Great Britain and the United States; about 1823 an Englishman, Mackintosh, immortalized himself by dissolving rubber in naphtha and waterproofing raincoats with the varnish thus obtained. Rubber articles of that time became soft and sticky in warm weather and hard and brittle in cold. The development of the vulcanizing process, invented by the American, Goodyear, in 1839, is quite comparable in significance to the invention of the cotton-gin or the evolution of the internal-combustion engine. The first process of vulcanizing consisted in strongly heating rubber in contact with sulphur, whereupon it lost its objectionable reaction to changing temperature, became more elastic, but still retained its waterproof nature.

The subsequent history of rubber is a kaleidoscopic sequence of exploitation of the wild rubber plants of South America and Africa, of experimental and commercial development of rubber plantations in Malaya and the South Seas, and of the bewildering evolution of new utilities of rubber in the rapid course of modern life.

Rubber in South America

THE BRAZILIAN RUBBER TREE

Rubber-yielding species abound in the Amazonian jungles and throughout northern South America. One species, however, stands preëminent—*Hevea brasiliensis* of the Euphorbiaceæ (Fig. 133). Formerly the chief source of rubber, when that came mainly from the Amazonian jungle, and still exploited there more than all other species combined, it has been also the principal tree of the eastern island plantations which have robbed Brazil of her rubber supremacy. Probably 95 per cent of the huge output of modern rubber is from the Brazilian Rubber Tree. The species is also known as the Para Rubber Tree.

Hevea brasiliensis is found throughout the Amazonian jungle region, a territory embracing northern Brazil and parts of eastern Bolivia, Peru, and Ecuador. The tree attains a height of 60 to 125 feet, a circumference of 8 to 10 feet, and an age of perhaps 200 years. The leaves are trifoliately compound; the smooth ovate leaflets are some two feet in length. The flowers are monœcious and apetalous. The fruit (Fig. 134), is tri-partate, splitting open at maturity and expelling the three large seeds with some force. The seeds are about an inch in length and have considerable resemblance to those of the related castor-oil plant. They are variously speckled and marked; under plantation conditions where seeds are saved from particular trees, the markings are often so characteristic that the produce of individual trees can be easily sorted from a mixture. Like most seeds of the Euphorbiaceæ, these are reputed poisonous; but they do not seem to injure deer or wild pigs, which devour them eagerly and are a considerable obstacle to natural reproduction of *Hevea* in the jungle.

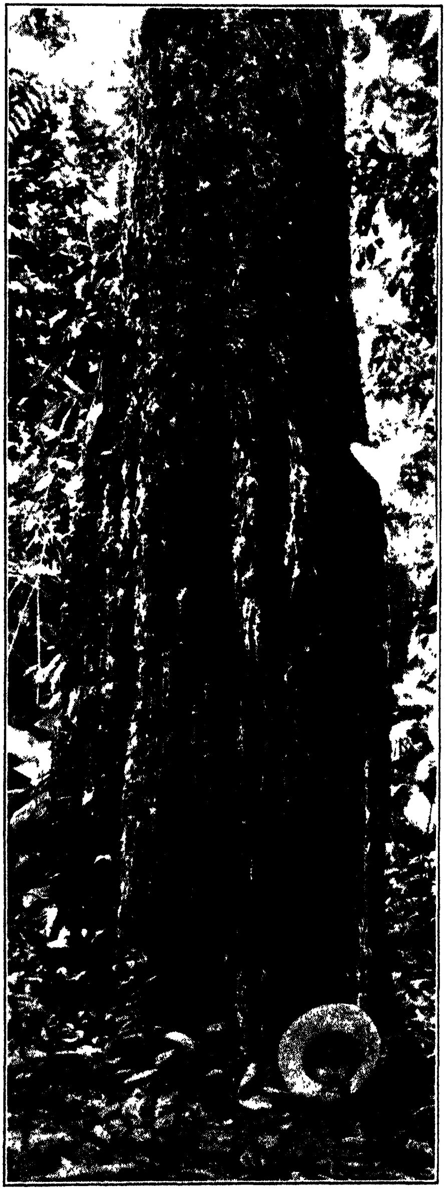

FIG. 133. — A Very Old Tree of *Hevea brasiliensis* in Brazil. The excrescences caused by tapping have formed ridges. The ridges have been re-tapped until the whole lower trunk has become fluted. (Courtesy of Bureau of Plant Industry.)

Hevea brasiliensis is a member of a fairly large genus, of which several others, including *H. Benthamiana* of the northern Amazonian region and *H. discolor* of the Rio Negro, are minor sources of rubber.

THE COLLECTION OF BRAZILIAN RUBBER

The South American product of *Hevea* is practically all from wild trees. Occasional plantations have been set, but the difficulties of contending with the jungle, the primitive and unreliable nature of the labor of these remote regions, and rubber-price fluctuations have discouraged capital investment, and the Brazilian government has done little to promote rubber-growing.

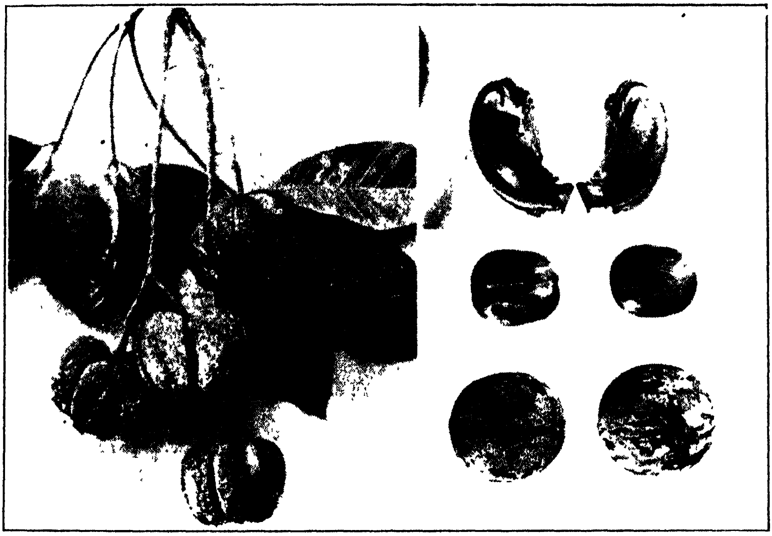

FIG. 134. — Leaves, Fruit, and Seeds of *Hevea*. (Courtesy of F. E. Lloyd.)

Rubber collectors of the Amazon are known as *seringueiros.* They are commonly of mixed blood—Portuguese and Indian, with not infrequently a dash of Negro; probably in general the Indian blood predominates. Technically they are free laborers; practically they are little better than serfs, bound by agreement to the owners of the rubber estates who advance money and supplies against future collections under a system which keeps the unfortunate *seringueiro* perpetually in debt. In an intelligence test, the *seringueiro* would probably fare badly in competition with a Malayan plantation laborer; efforts to introduce in South America tools and methods used in plantation rubber tapping have met with little success.

Seringueiros operate in the jungle alone or in loosely organized groups. *Hevea* trees are found irregularly scattered throughout an almost impenetrable jungle, which the rubber operators traverse as much as possible by means of its numerous water-courses. A *seringueiro,* or party of them, connects trees as located, by means of a trail called an *estrada.* An *estrada* links from 50 to 300 or more trees, depending on the terrain and number of workers.

Tapping and Collection.—Trees are tapped in the early morning by hacking the bark with a small heavy iron axe called a *machadinho.* In plantation practice, a sharp knife is used and care is taken not to injure the cambium, but a lusty blow of the *machadinho* is likely to carry well into the wood, and the bluntness of the clumsy instrument insures a wound which, while perhaps yielding latex a little longer than a clean cut, certainly heals more slowly and with more chance for fungus infection. The humid heat of the jungle, moreover, promotes fungus growth. Below the axe-wound is placed a tin cup, whose sharp-edged brim is thrust into the bark with sufficient force to keep it in place as it fills with latex. Flow begins as soon as the wound is made, but slackens as the temperature rises toward mid-day. Several incisions may be made on the same tree. Trees are tapped about twice a week for six months or more; at the end of that time the bark is generally thoroughly lacerated as high as hand-reach. If trees are not allowed seasons of recuperation their bearing life is likely to be short—not because of loss of latex, but because of cambium destruction, insect attack, and wood-rot. Some old trees exist which have been tapped for fifty years or more; the trunks of these are generally disfigured with swellings and burl-like excrescences due to careless wounding.

When the day's flow ceases the latex-cups are emptied into a tin pail or *baldé;* this, when filled, is poured into a rubber-covered cloth bag which the *seringueiro* carries in a wicker frame on his back.

Coagulation.—If latex is allowed to stand, the hydrocarbon globules rise, much as cream rises from milk. Commercial rubber, however, is coagulated by artificial means; in the Amazon region, almost wholly by smoke over semi-open fires built in rude huts in the forest. A ball of rubber may be started by wrapping a film of air-coagulated material around the end of a stick about six feet in length. This rod is thrust across a framework of two other poles and rotated over the smoke of a fire built on the ground or in a pit. Smoke is guided somewhat by a cone of baked clay or of tin. The fruits of the palm *Attalea excelsa* are especially valued for rubber-smoking; they release dense clouds of oily smoke which is supposed to impart superior quality to the rubber. Other fuels are also used.

Latex collections are placed in a pan behind the smoking-cone. From time to time as much as will remain without dripping is poured over the matrix at the end of the rod, which is slowly rotated on the frame over the smoke. The work goes on till the day's gathering is coagulated, after which the ball is rolled and kneaded to shape it and to expel liquid-remnants. Collections of successive days are added until the ball reaches the desired size. The usual weight is about 65 kilos.

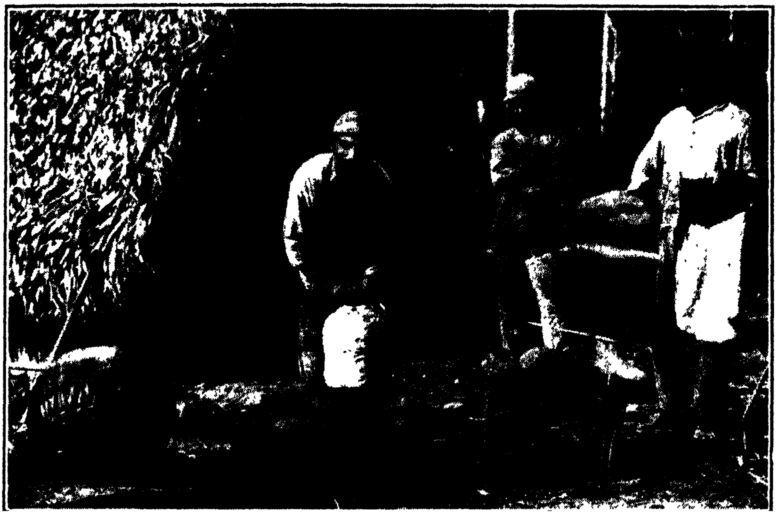

FIG. 135. — A Seringueiro Rolling a Ball of Freshly Coagulated Rubber. This shapes it and pressed out bubbles of air and vesicles of liquid. At the left is a finished ball of fine hard Para rubber; behind it is the thatch of the smoking-shed. The rubber shoes in the foreground were made by coagulating the latex over the wooden mold. The man at the right holds a cloth bag which has just been coated with latex. (Courtesy of Bureau of Plant Industry.)

Hand-smoking in ill-ventilated huts is a most unhealthful process, and the *seringueiros* suffer from respiratory and other occupational diseases.

Knapsack rubber (Fig. 136) consists of smaller flattened cakes, each of a single day's collection, smoked over a rectangular paddle, which is then withdrawn, leaving a knapsack-like cavity.

Sernamby is a low-grade mass of naturally coagulated lumps and films which collect in the tree and in or on the various vessels used.

The season's collection of a *seringueiro* usually varies between 600 and 1,000 kilos.

Fig. 136. — Knapsack Rubber. (Courtesy of Bureau of Plant Industry.)

The best grade of Brazilian rubber is marketed as *Para rubber*. Para rubber bears the highest reputation for durability and elasticity, and for some purposes is still considered superior to plantation rubber. Much higher yields could doubtless be secured by better tapping methods, but under present conditions little improvement seems likely to take place.

OTHER RUBBERS OF SOUTH AND CENTRAL AMERICA

Caucho Rubber.—Of some dozens of rubber-yielding species of South and Central America, only a few are of present-day importance. Probably second in importance to Para is caucho rubber, obtained from various species of *Castilla*, of the Moraceæ. *C. ulei*, the principal species of the Amazon Valley, is a large tree found on the high grounds above flood-level of the river.

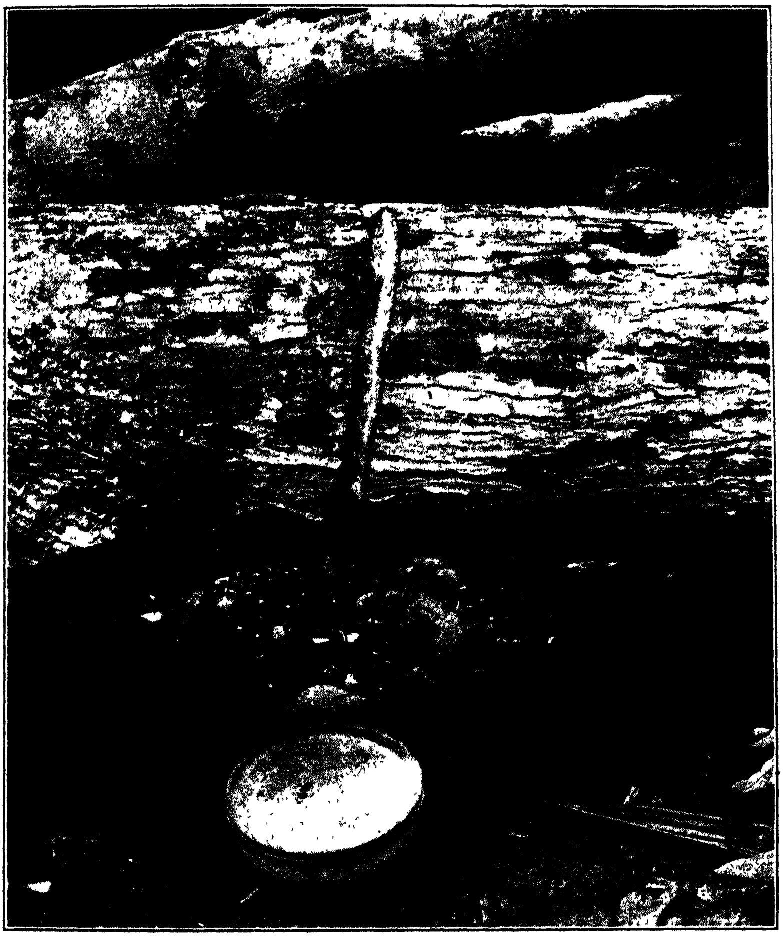

FIG. 137. — Collection of Latex from a Felled Tree of *Castilla ulei*. In thi case a cup is used, but more often the latex is simply allowed to drip into a hol in the ground. (Courtesy of Bureau of Plant Industry.)

These trees are usually cut down and the latex obtained by girdling cuts in the bark. The latex is allowed to flow into pools o the ground or more rarely into cups (Fig. 137). There it undergoes a partial putrefaction, as a result of which the rubber sepa rates. While the tree is widespread in distribution, this wastefu process of collection has much depleted accessible supplies. Caucho rubber is considered inferior to Para, and its repute is not enhanced by its usual mixture with dirt and debris.

Other Rubbers.—Other species of *Castilla* occur in Central America and Mexico. At one time *C. elastica* was much used in plantings in Mexico and elsewhere, but it has wholly disappeared since the superior merits of *Hevea* became known. The tough, fibrous bark of *Castilla* renders tapping difficult, and wounds heal slowly. Latex flows rapidly, but tends to separate at once—a disadvantage. Frequent tapping is disastrous. For commercial plantings, *Castilla* has been a decided disappointment.

Several South American species of *Sapium* and *Manihot* (Euphorbiaceæ) yield unimportant supplies of rubber.

Rubber in Africa

FUNTUMIA AND LANDOLPHIA

A considerable number of African trees and vines yield latex. Those principally exploited have been species of *Funtumia* and *Landolphia* of the Apocynaceæ. *Funtumia elastica* is a tree about 100 feet in height, first discovered in the British possession of Lagos about 1894. At that time it was plentiful in the tropical forests, but it was soon all but exterminated by most barbarous methods of collection. Trees were cut down; the bark slit, and the latex, which coagulates with difficulty, hardened by boiling. The bark was then peeled and beaten into pieces, from which the rubber was worked out and formed into balls. In some cases ladders and slings were used in tapping trees to a height of fifty feet or more, by methods almost as fatal as felling. Under such a ruthless system, Lagos rubber soon disappeared from the market.

The central regions of Congo Free State were next exploited. Here the principal rubber sources were *Landolphia* and other rankly growing woody vines, some of which reach a trunk diameter of six inches or more. *Landolphia* climbs the tall trees of the jungle by means of hook-tendrils. These vines were cut, dragged down, and divided into short lengths. The latex flowed out and hardened on the ground or on wound-surfaces, coagulation being aided by the high natural heat of the region. Vines were also cut and dried, after which the rubber was secured by maceration. Rather uncommonly, living vines were tapped.

BARBARITIES OF THE CONGO

Far worse than the waste of the forests was the human savagery of Congo rubber production. The so-called Congo Free State was at that time virtually the property of the Belgian crown, and the crown was worn by Leopold II, a monarch whose rule in Europe attracted no special remark, but whose administration of the Congo was one of the blackest chapters in the history of supposedly civilized mankind. Principal resources of the region were rubber and ivory, and collection of both was enforced on the helpless natives by the most abhorrent means. Villages were "taxed" huge quantities of ivory and rubber; negroes failing to produce their quotas were flogged, tortured, mutilated, or killed in cold blood. Women and children were held as hostages to be ransomed in rubber; and they were whipped, brutalized, and disfigured when ransom failed. The "hand-maimed host" of the Congo is said to have been numbered in thousands and tens of thousands. For constabulary in the rubber forests, cannibals were recruited and allowed to commit the most bestial excesses. For years these things were secret, but shortly before his death the villainous rule of Leopold in the Congo was terminated by the outraged public opinion of the world.

FUTURE PROSPECTS OF AFRICAN RUBBER

Africa seems to promise little as a future source of rubber. In many regions laticiferous plants have been practically eradicated. *Funtumia* and *Landolphia* are not particularly adapted to cultivation or to the methods of tapping which are successful with *Hevea.* African natives are perhaps the most ignorant and ineducable of rubber collectors. The marketed product, which by nature is fairly good, is usually much reduced in value by contamination or deliberate adulteration with dirt or other heavy substances. Cessation of collection may permit a partial return of the rubber species in the jungle; but, if low prices of plantation stock continue, their product is not likely to be harvested. Plantations of *Hevea* have been established in Liberia and elsewhere, and *Funtumia* has been experimented with in the Congo. As an African crop, rubber species are usually interplanted with other products. While low labor costs are reported, labor conditions in general are said to be less satisfactory than in Malaya. First the World War and later the low-price period greatly interfered with the development of cultivated rubber in Africa.

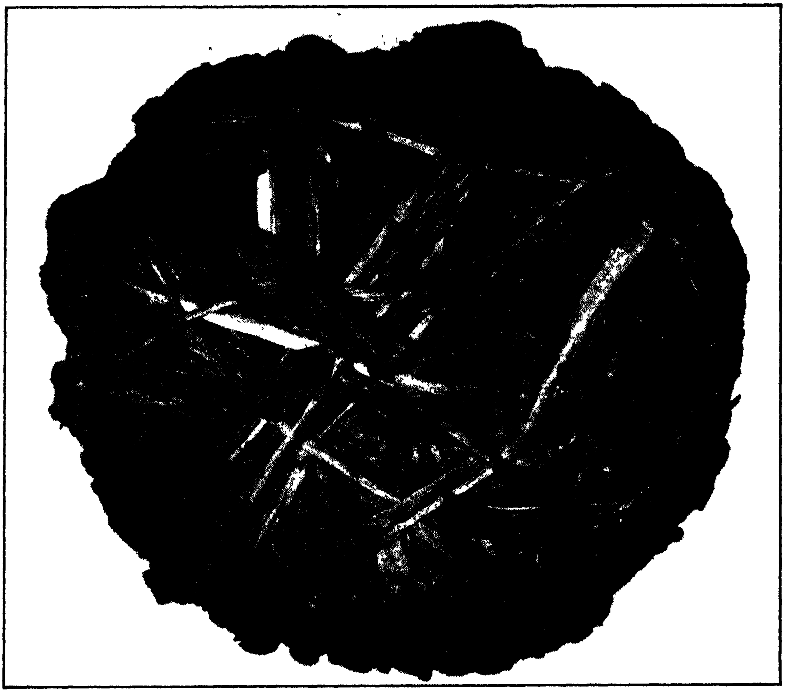

FIG 138 — Commercial Ball of Intisy Rubber, Formed from Strands Dried on the Tree. (Courtesy of Bureau of Plant Industry.)

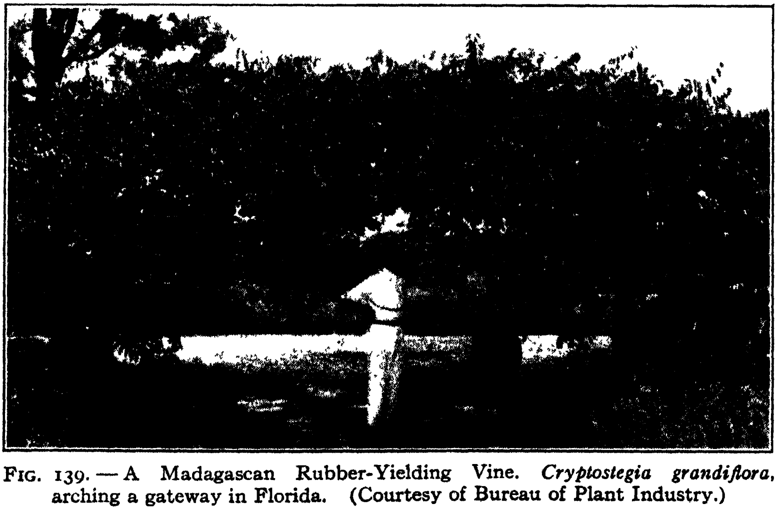

FIG. 139. — A Madagascan Rubber-Yielding Vine. *Cryptostegia grandiflora,* arching a gateway in Florida. (Courtesy of Bureau of Plant Industry.)

MADAGASCAN RUBBER

The large island of Madagascar was at one time a considerable source of rubber supply. There, rapacious collection has nearly brought to extinction one of the most interesting of rubber-yielding plants, the almost leafless xerophyte, *Euphorbia Intisy.* This plant is found in almost arid deserts. Upon its incised surface the latex exudes and hardens into elastic strands of high-grade rubber. These strands are rolled into balls (Fig. 138) and marketed. Intisy and species of *Cryptostegia* (Fig. 139), Madagascan rubber-yielding vines of the Asclepiadaceæ, are being experimentally grown in the United States. Intisy offers an interesting possibility for the hundreds of thousands of acres of American desert, in regions at present almost, if not quite, worthless. Intisy withstands long dry seasons by retention of water in sausagelike swellings of its roots (Fig. 140).

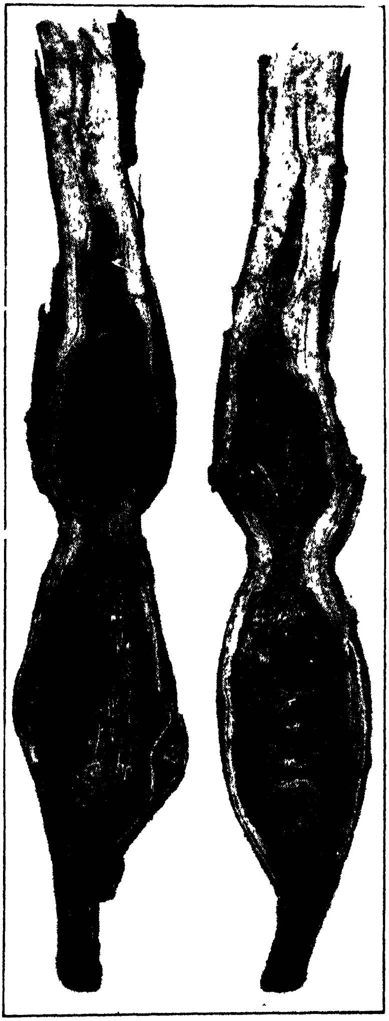

FIG. 140. — Lower Stem Portion and Sausagelike Water-holding Roots of *Euphorbia Intisy.* (Courtesy of Bureau of Plant Industry.)

Rubber in Asia

Assam, Rambong, or East Indian rubber is the product of *Ficus elastica* of the Moraceæ, more familiar as the "rubber plant" of conservatories. In its native regions, southern Asia, Malaya, and the South Sea Islands it is a huge and widely distributed tree, whose massive branches are supported by prop-roots like those of the related banyan. Before plantation development this rubber was of some importance, but it is of inferior quality and is now rarely seen. Whether the term "india-rubber" was derived from this, or whether it came from the habitat of other early-known rubbers in the West Indies, is a question upon which opinions differ.

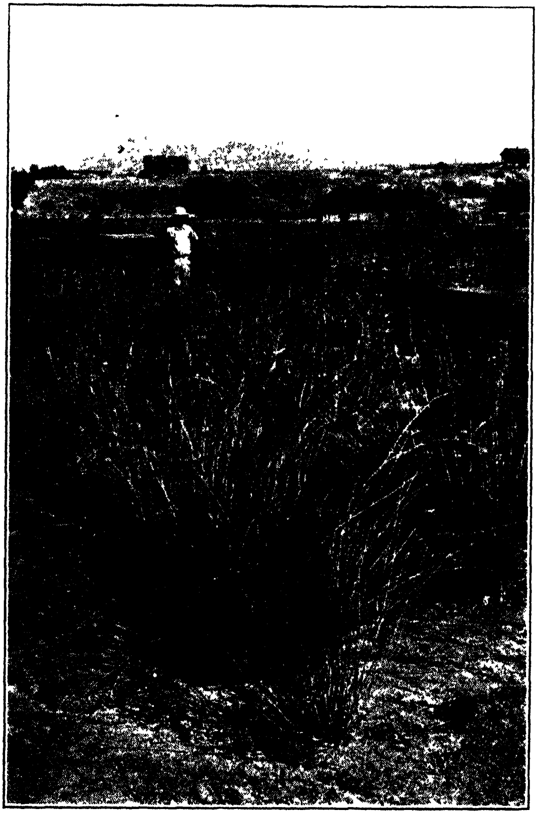

FIG. 141. — Experiments with Desert Milkweed at the United States Acclimatization Garden, Bard, California. Most of the plants are the nearly leafless Awl-stemmed Milkweed (*Asclepias subulata*), which grows much like a grass crop and could be harvested the same way. (Courtesy of Bureau of Plant Industry.)

Plantation rubber, which is mainly a product of Asiatic islands and the South Seas, will be discussed under a later heading.

Rubber in North America

While rubber-yielding plants are of common occurrence in temperate zones, practically no commercial rubber has yet been obtained from such regions. The tropics furnish huge trees and woody vines yielding latex, but the laticiferous plants of the north are mostly herbaceous. The plantations of *Hevea,* therefore, seem to be out of the question for us, but the possibility of field or desert culture of herbaceous sources of rubber has been much discussed. Naturally, the problems of culture, harvest, and rubber-recovery would be wholly different from the tapping of *Hevea* or *Castilla.* As long as plantation rubber continues cheap and abundant, there would seem to be little prospect of commercial production of natural rubber in the United States. American capital in recent years has been very active in the plantation rubber industry and, under peaceful conditions, can doubtless supply itself from tropical sources for a long time to come. World War memories, however, will always cause misgivings over total dependence on far-off climes for such a vital necessity as rubber.

LATICIFEROUS PLANTS OF THE UNITED STATES

Among herbaceous rubber possibilities within our own borders, most attention has been attracted by species of Milkweed (*Asclepias*) and Indian Hemp (*Apocynum*). Stems of *Asclepias subulata* (Fig. 141), a desert milkweed of the west and southwest, yield 2 to 6 per cent of their weight in low-grade rubber. This species thrives in almost worthless land, and its fibrous residues have been experimentally made into paper after the extraction of the rubber.

NON-LATEX RUBBERS

Several genera of the Compositæ contain rubber, not in the usual form of latex, but in that of solid or semi-solid particles in cells of the bark. Among these genera are *Parthenium, Solidago,* and *Chrysothamnus.*

Guayule.—Parthenium argentatum, or Guayule (Fig. 142), is a low-growing silvery desert shrub of Mexico, whose rubber-yielding capacity was known to aborigines of that country. Quantities of this are gathered in Mexico, and some is cultivated there. Mexico exports several million pounds of guayule rubber annually. The principal experimental work with guayule, however, has been within the United States—in Arizona and particularly at Salinas, California, where the work has been under way since 1911. Through intensive botanical, chemical, agricultural, and industrial experimentation, major difficulties of cultivation have been overcome. High-yielding strains have been established under field conditions, and ingenious processes of planting, transplanting, harvesting, and rubber-separation have been devised.

Guayule yields about 15 per cent of its weight in rubber; an acre produces some 1,500 pounds at four years from planting.

The original process of guayule rubber-separation consisted simply of mastication in the Indian mouth. Despite recent anti-immigration propaganda as to the reproductive efficiency of the Mexican family, this process does not lend itself to large-scale production. Modern milling of guayule consists essentially in crushing the whole plant and disintegrating the fibrous mass in water so as to free the rubber particles, which rise to the surface and are skimmed off. The crude rubber is cleaned by hydraulic pressure processes, rolled into sheets, washed, and dried.

FIG. 142. — Guayule (*Parthenium argentatum*); a Wild Specimen Collected in Mexico. (Courtesy of F. E. Lloyd.)

Guayule rubber is dark gray in color; its quality for most purposes is said to be inferior to Para or plantation rubber, but there are certain uses in the construction of automobile tires for which it is said to excel.

Goldenrod Rubber.—*Solidago* (Goldenrod) is a large genus of common and well-known plants, with especial distribution in the East and Central West. Much popular interest has attached to goldenrod rubber because of the investigations of Edison, which received much publicity. At the time of the great inventor's death, commercial production had not been attained. It is understood that his experiments with the goldenrods are being continued.

Plantation Rubber

It has been previously indicated that interest in planted rubber species has been wide in geographical range and has concerned itself with numerous plants. The rubber which dominates the industrial world of to-day, however, is almost wholly from plantations of *Hevea brasiliensis* in the British possessions of Malaya and Ceylon and in the Dutch East Indies. Smaller plantations of *Hevea* have been established in India, Burma, French Indo-China, Borneo, the Philippines, Liberia, and elsewhere in the tropics.

Fig. 143. — Cortical Cells of Guayule, Highly Magnified. Rubber is shown in the form of minute suspensoids. (Courtesy of F. E. Lloyd.)

THE GENESIS OF PLANTATION RUBBER

Seeds of *Hevea* were first obtained by an Englishman, Wickham, in Brazil. These were planted in the Royal Botanic Gardens at Kew, England, in 1876. Of 70,000 seeds planted, only 2,700 germinated. Seedlings were carried in miniature greenhouses, called Wardian cases, to Ceylon. Some of these, now considerable trees, still stand in the Botanical Gardens at Peradeniya. Others were later transplanted to Singapore and Perak. In 1881, fruits and seeds were borne by Wickham's trees. From such small beginning has developed a plantation industry which, in 1929, covered 6,000,000 acres of former tropical jungle, producing an annual rubber crop of over 600,000 tons—twenty-fold more than the harvest of Brazil.

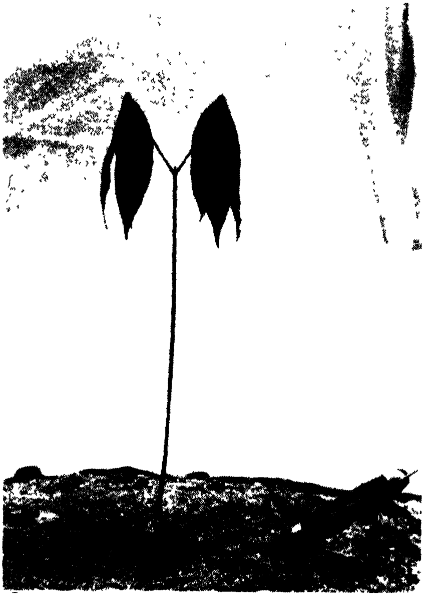

FIG. 144.—A Seedling of *Hevea*. (Courtesy of F. E. Lloyd.)

PLANTATION CULTURE AND HARVEST

Hevea seedlings are started in nurseries and later transplanted into the laboriously cleared jungle. Yields of individual trees vary, and much attention has been paid to the development of high-yielding strains by seed-selection from high-yielding stock. Budding (Fig. 145) has also been practised in a limited way with generally good results, although because of bud variations, or possibly because of influence of stock on scion, budded trees do not always equal the parent in production. *Hevea* does not lend itself to profitable reproduction from cuttings.

Rubber trees grow rapidly, sometimes as much as six feet in the first year from seed. At five years they may reach a trunk-girth of about eighteen inches, and at that age tapping is begun. As in Brazil, this work is done in early morning, but in other details the process differs. With a chisel-like knife a narrow diagonal cut is made, extending half around the tree (Fig. 146). The laticiferous tissues are thus severed, but the cambium is carefully avoided. Below the cut is inserted a small spout, which carries the latex to a porcelain cup placed beneath. When the flow stops, the liquid is promptly gathered. Subsequent tappings are made by stripping a thin shaving of bark from the lower surface.

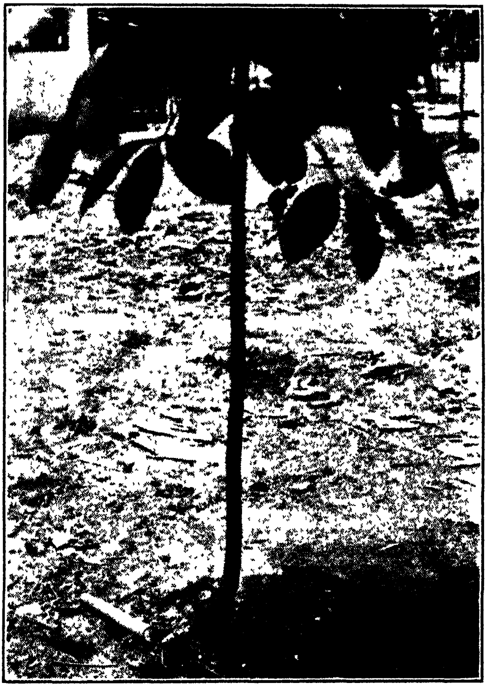

FIG. 145. — A Budded Rubber Tree, Showing Growth from the Bud. The shoot of the seedling above the point of insertion of the bud has recently been cut away. (Courtesy of United States Rubber Company.)

On some plantations the herring-bone system of tapping is used; in this diagonal cuts from both sides connect with a central channel, below which the cup is placed.

Tapping periods vary with rubber-demand. They may run from two to eight weeks and even more; they should be followed by similar resting periods. The bark of a tapped area is renewed in about four years.

RUBBER YIELDS

Small trees naturally yield less than large ones. For the first year of tapping, not more than half a pound of rubber per tree is usually obtained. Mature trees yield four or five pounds. As to individual variations in yield, Lloyd[1] cites two trees on a Sumatran estate which produced respectively 911 and 14.5 grams of dry rubber in a month (Fig. 147).

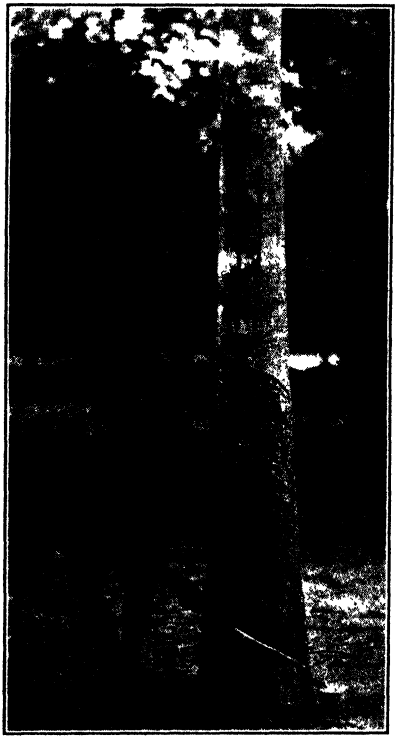

FIG. 146. — Tapping a Rubber Tree on a Plantation. (Courtesy of United States Rubber Company.)

"Assuming one hundred trees to the acre, the yield from a population of such poor trees would be about thirty-five pounds, from the better two thousand two hundred pounds! An average population produces three hundred pounds (or less) to six hundred pounds, according to circumstances of the soil, rainfall, etc., but a flat average of four hundred pounds would be considered very good. . . . For the purpose of selection it is imperative to judge by yield alone, as it has been found that there is no character . . . not even that of the number of rows of latex vessels . . . which has a close enough correlation with yield to permit it to be used as a certain guide."

FACTORS CONTRIBUTORY TO PLANTATION SUCCESS

Rubber production in Malaya and the Dutch East Indies is favored by climate, soil, and particularly by abundant supply of cheap, tractable, and sufficiently intelligent labor. Rough-and-ready tapping methods of Brazil, and the wastes and brutalities of the African forests, have no place there. The rubber industry, started under the tutelage of the British government, has developed and spread into Dutch territory in Sumatra and other islands, keeping pace with the tremendous demand for rubber in modern life, and, particularly, with the development of the automobile. It entered the South Seas as the coffee leaf disease (Chapter XV) drove out what had there been the chief agricultural and commercial interest; peculiarly enough, the fragrant berry proceeded to establish itself in its present world center, Brazil—a curious exchange of staple products!

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[1] Francis E. Lloyd, "Plantation Rubber: Its Source and Acquisition," *Scientific Monthly,* XXIII (1926), 268–278.

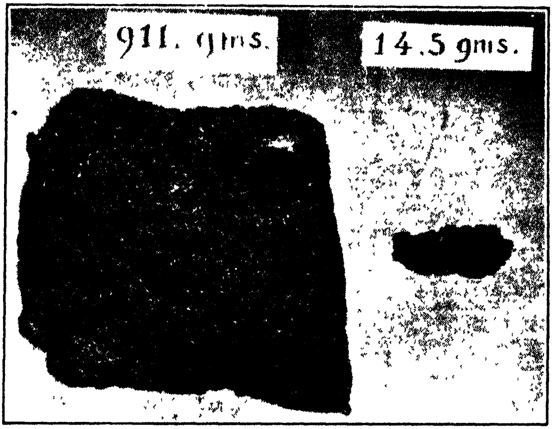

FIG. 147. — Monthly Yield of Coagulated Rubber from the Best and Poorest of One Thousand Trees. (Courtesy of F. E. Lloyd.)

The great demand for plantation rubber and the profits reaped (for a time) have attracted abundant capital—British, Dutch, and, more lately, American. By arduous research, every phase of planting, cultivation, tapping, and coagulation has been explored. Insects and disease, always hazards in the tropics—and *Hevea* has its full share—have been vigorously studied and combated. In the more modern plantations, sanitary quarters are afforded the workers; their health is carefully guarded. One American rubber firm claims the largest private hospital in the East. The entire administration is lauded as model for the Orient. Rubber, which brought death and disaster to the Congo, brings civilization to the South Seas. The continued compatibility of advancing civilization with low wages remains to be demonstrated—with profit, which makes even low wages possible, vanishing.

PROCESSING OF PLANTATION RUBBER

Acid Coagulation.—Plantation rubber is usually coagulated by the addition of acetic acid to flat pans of fresh latex; this causes the rubber to collect as a sheet on the surface. Sheets are passed through rollers, which press out excess moisture and leave a wrinkled pattern on the surface. This rubber is known as crêpe rubber. It is a purer, dryer product than that of Para. As to the relative values of the two, conflicting statements are made. In Brazil, young trees are said to produce inferior rubber; *Hevea* is not generally tapped until it reaches considerably greater age than the average plantation tree. This may account for some of the alleged inferiorities of the plantation product. So varied are the uses of rubber that no single grade or kind is best for all purposes. As an attempt to approximate more closely the characteristics of Para rubber, the coagulated sheets may be smoked for several days.

Sprayed Rubber.—Sprayed rubber is made by a process developed by an American firm. Latex is dripped from a storage tank upon a rapidly revolving disk, which whirls it off as a fine white mist into a current of hot dry air. The moisture is thus evaporated immediately, and tiny particles of rubber fall. All the rubber in the latex is obtained as a high-grade, perfectly clean product. This method avoids the difficulty of adjusting acid-treatment to varying concentrations of latex collected during rainy periods when water gains access to the collecting-vessels.

Preservation of Latex.—While latex ordinarily soon separates, addition of ammonia retards this process. Large quantities of liquid latex so treated are now being brought to the United States and shipped in tank cars to the rubber factories. This idea is a recent one. While shipment of the bulky fluid is of course expensive, for some purposes the latex is preferable to coagulated rubber, and its importation seems likely to increase.

The Rubber Trade of the World

A résumé of recent rubber commerce is given in Table III.

This emphasizes the dominance of the Far East. To indicate the recency with which this has been attained, it may be said that of the world-exports average of 289,064,000 pounds per year for the period 1909–1913, Ceylon contributed about 11,000,000 pounds; the regions now embraced in British Malaya, about 31,000,000 pounds; Netherlands and the Dutch East Indies, about

14,700,000 pounds; Belgium and Belgian Congo, about 28,400,000 pounds; while Brazil far outstripped any other exporting country with nearly 85,000,000 pounds. In no major agricultural product has there been anything like the rise of plantation rubber in the last two decades. To it have contributed the vast industrial consumption of rubber, the demands of the World War, the stimulation of attempted monopoly, and many other factors.

From the point of view of profit, plantation rubber reached its zenith about 1926. From a highly lucrative price during the World War, plantation rubber slumped sharply in 1921–1922. At this time rubber production was nearly a British monopoly; in order to increase and stabilize price, the so-called Stevenson Plan was put in operation. Under this, tapping in British possessions was curtailed, and the price rose sharply, an average United States import price of 61.6 cents per pound being paid for rubber in 1926. Such a level, however, could by no means be maintained. Dutch producers increased their output; American rubber manufacturers poured into the plantation field, particularly in the Dutch possessions; reclaimed rubber competed with crude; and an active search for rubber substitutes, begun during the war, continued at doubled pace. In 1928 the Stevenson Plan was abandoned; the falling price of rubber was accentuated not only by uncontrolled output but by depression-decreased demand. In 1932, plantation rubber was said to bring not more than one-third the cost of production.

Uses of Rubber

So numerous are the uses of rubber, and so well known are most of the principal ones, that it may seem scarcely worth while to catalogue them. The United States is the world's principal consumer of crude rubber, and the rubber industry is one of its largest manufacturing interests. We utilize about 70 per cent of the world's annual supply. For census purposes, the rubber industry reports under three headings: (1) RUBBER TIRES AND INNER TUBES, (2) RUBBER BOOTS AND SHOES, and (3) RUBBER GOODS NOT OTHERWISE CLASSIFIED. Of these the first—while last to develop—is of predominant volume. In 1927, according to the Rubber Association of America, the sales value of tires and tubes was over 75 per cent of the entire sales of the rubber industry, and its consumption of crude rubber 85 per cent of the total. The rubber shoe industry is much older, dating from about 1830; in aggregate value it ranks lowest of the three classes, but it still produced products priced at nearly $125,000,000 in 1927. Among other

TABLE III

Rubber, International Trade for Years Stated in Thousands of Pounds *

COUNTRY	CALENDAR YEAR							
	1925–1929 (average)		1929		1930		1931 [1]	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
Principal Exporting Countries								
British Malaya	931,522	362,113	1,300,117	362,011	1,247,342	304,331	1,162,535	280,972
Dutch East Indies	593,755	0	664,555	0	616,332	0	653,125	0
Ceylon	133,621	11,137	180,632	13,377	170,946	11,155	138,005	6,991
Brazil	46,638	0	39,643	0	26,689	0	23,096	0
British India	23,532	100	26,259	271	24,153	260	18,979	369
Indo-China	20,509	[2] 29	22,726	[2] 60	23,046	108	....	....
British North Borneo	14,419	0	16,534	0	15,937	0	....	0
Mexico	8,440	566	3,261	1,139	2,688	6	....	....
Bolivia	7,474	[3] 1	6,818	....	....	....	....	....
Nigeria	3,947	0	4,422	0	4,877	0	....	0
Kamerun [2]	3,818	1	4,420	0	3,601	....	....	0
French Equatorial Africa	3,242	[2] 211	[2] 2,365	[2] 213	1,578	122	....	....
Belgian Congo	2,230	1	1,872	0	1,126	0	550	0
French Guinea	2,046	[2] 30	[2] 830	[2] 4	[2] 571	......	....	....
Switzerland	1,939	1,155	2,624	1,466	2,566	1,813	2,104	1,893
Ecuador	1,756	0	409	0	318	0	....	0
Gold Coast	889	0	649	0	540	0	221	0
Peru	526	0	543	0	284	0	81	0
Angola	179	0	29	0	13	0	....	0
Total	1,800,482	375,344	2,278,708	378,541	2,142,607	317,795	1,998,696	290,225

Principal Importing Countries								
United States	0	1,002,031	0	1,262,939	0	1,089,830	0	1,124,003
United Kingdom	0	124,052	0	275,088	0	268,806	0	190,818
France	16,049	106,453	7,478	140,400	5,685	159,147	2,751	119,438
Germany	6,051	87,825	7,119	117,054	11,469	113,365	11,551	99,330
Canada	0	59,580	0	79,512	0	64,492	0	56,583
Japan	0	50,307	0	76,922	0	73,710	0	97,548
Italy	351	27,855	81	36,700	149	41,735	24	22,639
Russia	0	23,145	0	28,278	0	36,173	0	62,192
Belgium	2,719	16,271	3,856	25,178	3,232	27,470	5,038	29,697
Spain	19	13,958	52	22,077	28	27,699	50	15,834
Netherlands	6,267	10,561	6,525	13,726	4,737	11,288	4,445	9,440
Austria	1,283	7,269	2,066	9,955	2,322	7,739	2,107	8,778
Sweden	144	5,420	107	8,527	102	10,097	66	8,736
Czechoslovakia	276	5,348	531	10,948	414	10,564	....	....
Hungary	213	2,291	227	3,316	134	3,216	185	3,170
Denmark	4	1,341	1	1,780	2	2,551	2,136	0
China	0	1,016	0	2,557	0	1,391	0	6,774
Total	33,376	1,544,723	28,043	2,114,957	28,274	1,949,273	28,353	1,854,980

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* From *United States Department of Agriculture Yearbook, 1933.* Bureau of Agricultural Economics. Official sources except where otherwise noted.

[1] Preliminary.

[2] *International Yearbook of Agricultural Statistics.*

[3] 2-year average.

manufactured rubber articles are druggist's products; mechanical rubber goods such as belting, hose, and tubing; rubberized fabrics, rubber heels, electrical goods, toys, hard rubber goods, etc. One authority views the development of steam-engine packing and other machine packings as the most important application of rubber, in that this use has been essential to the development and use of steam as a motive power.

Hard rubber, also known as ebonite and vulcanite, is composed of rubber which has been highly heated with about 30 per cent of sulphur. It is chiefly used in battery boxes; electrical supplies, including telephone and radio parts; combs; and druggists' sundries.

Artificial Rubber

The importance of rubber and its present production-monopoly by tropical regions, remote from manufacturing countries, have brought about both in Europe and America intensive efforts toward its replacement, synthesis, and artificial production. Casein-products and phenolic resins have in part supplanted hard rubber; oilcloths are used where rubberized fabrics might otherwise be employed; and various manufactured products have substituted for rubber, particularly in periods of high price. Germany, war-severed from Brazil and the Orient, found rubber a vital necessity. Throughout the conflict hundreds of German chemists worked night and day for the synthesis of rubber for aircraft and submarines. Several "war-rubbers" were evolved; these, while simulating the latex product in some respects, were in most ways inferior, and they were expensive to produce. By the end of the war the Germans had developed a highly ingenious but complicated process by which, starting from acetylene, a substance in close imitation of rubber could be synthesized. So expensive was the process, however, that it went out of use when rubber again became available.

Much more recently, an American chemical company has announced a new synthetic rubber, also based on acetylene. The primary materials are coal, limestone, salt, and water; the details of the process, most technical. X-ray studies show that the molecular structure of the new substance is very similar to that of natural rubber. The new product, however, differs from the latter in some respects and is not a complete substitute for it. It is said to be more resistant to gasoline and other rubber solvents than natural rubber and also to be less susceptible to oxidation in air, which makes rubber brittle. It can be vulcanized by heat without the addition of sulphur. A latex prepared from it has been used to impregnate naturally porous materials which resist natural rubber. Further researches are planned with view to the perfection and more general utilization of this product.

Such a process-rubber would be of incalculable value to a country isolated, as was Germany from 1914–1919, from the natural rubber sources of the world.

3. Other Latex Products

The principal latex products which are more or less similar to rubber in nature and use are jelutong or pontianak, gutta-percha, and balata. Another, of considerably different application, is chicle, the raw material of chewing-gum.

Jelutong

Of those mentioned, jelutong is closest to rubber; it owes its value, in fact, to its considerable rubber content. It consists of the coagulated latex of several species of *Dyera,* enormous forest trees of the Apocynaceæ, found and utilized chiefly in Borneo and Malaya. The term "pontianak" comes from a region and a port of the same name, of West Borneo.

The jelutong trees are found in dense swampy jungles. Bridgelike paths are made through these by felling trees in lines leading to the trunks of the jelutongs, which are knife-tapped on the herring-bone system. The collected latex is coagulated by stirring in a mixture of gyspum and kerosene, and the hardened product is sold in square or cylindrical blocks.

Jelutong contains 70–80 per cent of resinous material and 20–25 per cent of rubber. It is used as a rubber substitute and rubber source, particularly when rubber is high. It is a partial substitute also for gutta-percha. Recent attempts have been made to refine from it a chicle substitute for use in chewing-gum.

Gutta-Percha and Balata

The term GUTTA-PERCHA is derived from the Malay *geteh* (gum) and *pertja,* the vernacular name for a tree from which this product was at one time erroneously supposed to be derived. True gutta-percha is from the large evergreen tree ***Palaquium*** **(*Isonandra*)** ***Gutta*** and related species of the Sapotaceæ, of Malaya and the adjacent South Seas. Commercial "gutta-percha" and related substances are often of rather obscure origin, and they are likely to be of mixed character or adulterated.

The latex of *Palaquium* does not flow readily, and tapping as for rubber yields little. The original process of collection consisted in felling the tree and girdling inch-wide strips at intervals of about a foot. The latex exuded into these rings and was removed and purified somewhat by boiling. Maximum yields of two to three pounds of gutta-percha were obtained from trees about thirty years of age.

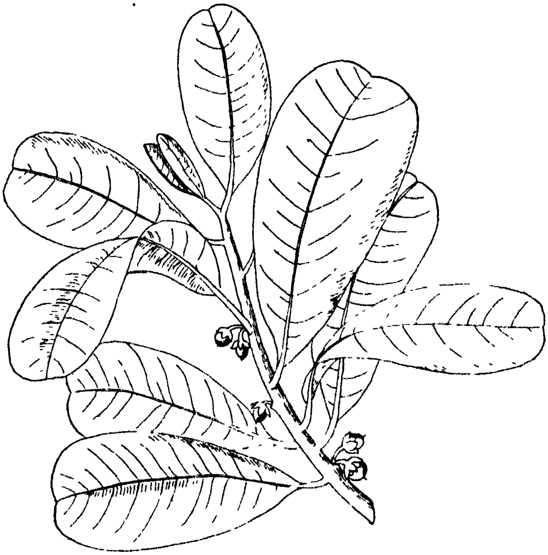

FIG. 148. — Branch of a Gutta-Percha Tree (*Palaquium Gutta*). (E. Coffman.)

This destructive exploitation has been nearly replaced by a plantation system. *Taban merah,* the most valuable variety, is grown from seed as a bushy shrub. The leaves are harvested and chopped and crushed while still fresh. The pulp thus obtained is treated with boiling water, which washes out the dirt and cellular debris. The resulting gum, amounting to 1.5 to 1.8 per cent of the weight of the fresh leaves, is pressed into blocks.

Taban merah plantations have been established largely through the agency of a British submarine cable manufacturing firm, which has had to overcome many difficulties of culture in its pioneer work.

The gutta-percha trade centers at Singapore.

Balata is a similar though usually inferior gum from *Mimusops Balata* of the Sapotaceæ, of the jungles of British Guiana and adjacent South America. Trees are tapped by slashing with a cutlass in feather-stitch fashion to a considerable height. The latex is allowed to flow into calabashes and coagulated in shallow trays. In British Guiana, the principal source, collection is stringently regulated by the government.

COMPOSITION AND USES OF GUTTA-PERCHA AND BALATA

Gutta-percha contains varying proportions—25 to 90 per cent—of a hydrocarbon known as gutta, to which its chief value is due. Gutta has the same empirical formula ($C_{10}H_{16}$) as the hydrocarbon of rubber, to which it is closely related. It is a yellowish, grayish, or brownish rather leathery solid, which softens and becomes plastic—but not very elastic—with heat and resinous—but not brittle—when cold. Gutta-percha is very resistant to water, and is often preserved for some uses under it, to prevent its becoming brittle by oxidation. Its principal use is in insulation for submarine telegraph cables. About 180 pounds of gutta-percha is used per nautical mile of cable; the total weight in use on the world's cable systems a few years ago was estimated as about 26,000 tons. Gutta-percha is also used in other electrical connections, in surgical instruments, in golf balls, and in dental practice as temporary filling for teeth and for taking impressions.

Balata is of very similar character. For many purposes it is considered inferior to the best grade of gutta-percha; but the latter is scarce, while there is a fair supply of good balata. It is considerably employed in beltings. For submarine telephone cables, balata is preferred to gutta-percha because of certain electrical properties which adapt it to the insulation of the currents of greatly varying frequency needed to transmit the human voice.

Chicle

Chicle is derived from the latex of *Achras Sapota,* the Sapodilla, of the Sapotaceæ. The sapodilla is a large forest tree ranging from Mexico southward to Venezuela and the Guianas; it is also cultivated in the tropics for its edible fruit. Chicle collection centers in Yucatan, which is heavily forested with sapodilla trees of several kinds; some is also gathered in British Honduras.

The tree is a fine, tall hardwood of slow growth, requiring seventy years to reach tapping size. Tapping is done through the wet season, from June to February. Maya Indian *chicleros,* or gatherers, climb the trees to a height of fifty feet or more (Fig. 150). With heavy knives—*machetes*—they slash the bark with V-shaped cuts, whose apices form a channel toward the base of the tree, where the latex runs down and collects in a vessel. Like rubber latex, that of the sapodilla flows best in early morning. About forty minutes are required to tap a tree, and six trees are an average day's work. Latex is fully drained by the following day. It is then collected and transported in canvas bags to a central camp, where the gum is coagulated by boiling in large metal pots.

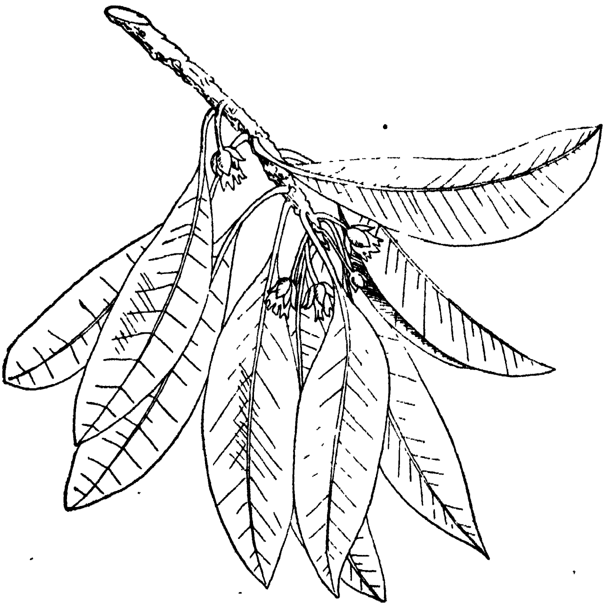

FIG. 149. — **Flowering Branch of the Sapodilla** (*Achras Sapota*). (E. Coffman.)

The best grade of chicle is nearly white; some sapodillas yield a pinkish or reddish gum, and overcooking also imparts a reddish color. The average yield of a tree is about two and a half pounds, and six or more years should elapse between tappings.

The crude gum is run into blocks of about twenty pounds, and transported on mule-back or in crude carts to shipping points.

HISTORY AND MANUFACTURE OF CHEWING-GUM

Chicle seems to have been chewed by the Aztecs and perhaps by their predecessors, but its large-scale use outside Mexico is quite recent. Histories of the annexation of Texas and of the Mexican War make prominent mention of one Antonio Lopez de Santa Ana, a militant Indian whose rule kept Mexico in internal turmoil and outside difficulty for several decades. Shortly before

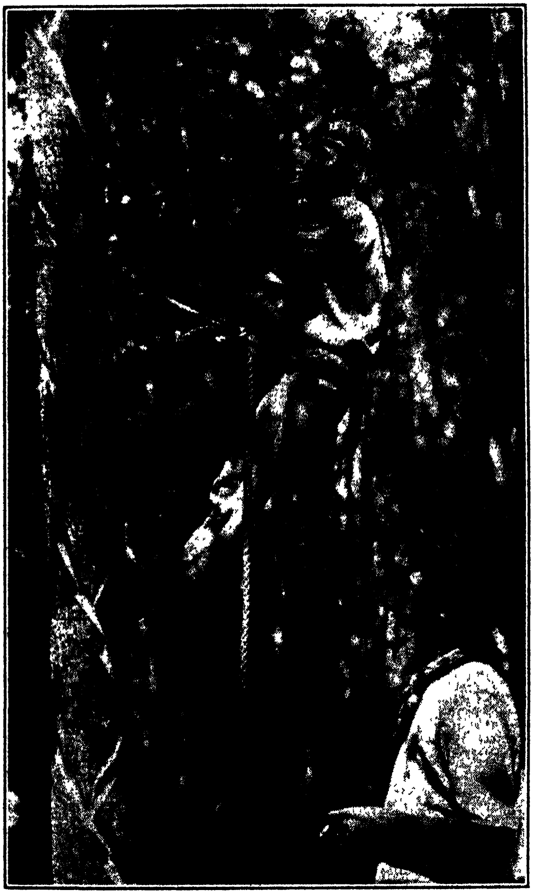

FIG. 150. — Chicle Hunters of Yucatan Cutting Gashes in a Sapodilla Tree. Each gash is cut so that the sap flows into the one below it and so down to the bottom of the tree, where it is caught in a bag or vessel. The sap is then boiled down into blocks which are shipped to manufacturers. (Photo by Ewing Galloway, N. Y.)

our own Civil War, Santa Ana was finally overthrown and found refuge on Staten Island, near the city of New York. Here he found some solace in the vigorous mastication of chicle. An inventive Jerseyman who observed the process conceived the idea that chicle should be an excellent rubber-substitute, but after some futile experimentation he abandoned that hope and became the first American manufacturer of chewing-gum.

The first chicle gum was unflavored, as used in Mexico. Later a licorice flavor was devised, and still later the various aromatics, of which spearmint is probably the favorite to-day. The process of gum-making is not a very complex one; it involves merely the thorough cleansing of the chicle and the incorporation of sugar and flavor. All processes, including wrapping, are carried out by machinery.

Raw chicle imports of recent years (1923–1928) have averaged about 8,800,000 pounds, with a value of nearly $4,400,000, annually. The majority of the nearly incalculable number of sticks of gum made from this are consumed in America. Before some millions of packages were sent over to the American doughboy, Europe knew little about chicle. With us, it has quite crowded out the brittle resinous "spruce gum" which preceded it; probably, also, it has been somewhat responsible for the decline in popularity of that other great American masticatory—chewing-tobacco. While various claims have been made for the value of gum-chewing, this constant rumination, particularly among the young, is probably merely an evidence of the traditional nervous restlessness of the American people. Certainly the habit is less obnoxious than the betel-chewing of the Hindu or the coca-leaf quid of the Peruvian Indian. Perhaps American education could continue without chewing-gum, but there seems little likelihood that it ever will.

CHAPTER VII

TEXTILE PLANTS AND PRODUCTS

1. FIBERS

The wool of sheep, the hair of various other animals, and many fibrous plant products were utilized by primitive man long before the dawn of record for the spinning of thread and cordage and the weaving of coarse fabrics. Among the earliest fabric materials was the fiber of flax; cotton, greatest of modern vegetable textiles, came later. Of the several hundred plant fibers known to-day, the great majority are of limited or primitive use. About a dozen—among which are cotton, linen, jute, Manila, sisal, henequen, and hemp—dominate textile and cordage trade of the civilized world.

Many plant textiles, such as linen and hemp, are grouped, elongated bast fibers found in barks of herbaceous dicotyledons. Others, including sisal and henequen, are from sclerenchymatic strands, or fibro-vascular bundles, of leaves or stems of monocotyledons. Cotton is almost the only epidermal hair used in fabrics.

The cell walls of vegetable fibers, like those of most other plant tissues, consist chiefly of cellulose. Cotton and flax fibers, in fact, are among the purest forms of cellulose found in nature; while the stiffer, more brittle, and often coarser structures of sisal, henequen, and jute are considerably lignified—a factor which in many respects detracts from their usefulness.

The Qualities of a Textile Fiber

Prior to the weaving of cloth, fibers must be twisted, or spun, into thread or yarn. Successful spinning and weaving depends on a variety of factors.

Durability in use and wear implies considerable tensile strength, which is conditioned by the diameter of the fiber or fibrous aggregate, by the cell wall thickness, and by the purity of the cellulose. Purity of cellulose is also conducive to pliability and elasticity, desirable qualities in which jute, manila, and other lignified fibers are somewhat deficient. Resistance to decomposition under moist conditions is also a valuable attribute; here manila excels, while jute is decidedly lacking.

Long fibers, other things being equal, are preferable to short ones. Fibers below 5 mm. in length cannot be properly spun. Individual cells of jute and hemp rarely exceed 4 mm., but commercial fiber, in all cases save cotton, is a complex cell-aggregate which may extend the entire length of the plant—300 cm. or more. Single cells of cotton range from 18 to 40 mm. in length.

The term STAPLE, commonly used in reference to cotton and other fibers, refers primarily to length, but also to fineness, of fiber or fibrous aggregate. Long staple is conducive both to efficient spinning and to strength of thread. Cotton and linen fibers are of very small diameter and thus are used for the finest of fabrics, while the coarser complexes of jute and manila find employment in sacking and cordage.

Frictional resistance, or cohesiveness, depends on irregularity of surface. Cotton fibers are flattened, thin-walled tubes with a natural twist; they tangle readily and do not slip apart easily when spun and woven. Linen and hemp lack natural twist, but have knotlike or nodelike annulations which, when the fibers are artificially twisted together, increase frictional resistance. Some artificial fibers, such as those of rayon or artificial silk, have very smooth surfaces and are not readily spun. Among natural products, the seed-hairs of milkweeds have a glassy "slickness" which, coupled with brittleness, prevents their use in spinning despite their attractive color and luster.

Pure whiteness and reasonably high luster are desirable qualities in a fabric; the former may be attained by bleaching and the latter by other chemical processes, as in the mercerization of cotton. Cotton and flax are readily bleached and dyed; the lignified fibers much less so. Porosity and absorbency largely depend upon purity of cellulose, and these qualities, increased by bleaching, facilitate dyeing.

Commercial availability is of course an important requisite. Many fibers of good quality are found in plants which do not yield readily to cultivation. The fibers of others, like ramie, are difficult to free from associated plant structures. All the important commercial fibers are from annual plants, or from perennials yielding annual harvest, and susceptible of large-scale cultivation. Some, such as cotton and flax, are of wide range; others, like jute, are of limited distribution, but—where they occur—they are intensively cultivated under favorable climatic and soil conditions and by cheap labor. Year-after-year constancy of supply and of quality are essential to the development of large-scale demand for any fiber.

2. COTTON

The Cotton Plant

Various species of *Gossypium* (Fig. 151), of the Malvaceæ, have long been cultivated in the warmer regions of both hemispheres. Those chiefly planted are rapidly growing, somewhat woody annuals which probably have been derived by selection from perennial ancestry. Above-ground parts are much branched and from two to four feet in height. Leaves are large and palmately lobed; of some interest is the occurrence of nectar-bearing glands on the lower surface of the principal veins. Flowers are large and showy, somewhat varied in color and markings. Those of American Upland cotton open white or pale yellow and later turn pink. Each flower has an involucre, usually of three bracts, which persist as the fruit ripens. The corolla is deeply five-divided. A hollow column, made up of the united filaments of numerous stamens, surrounds the style, whose several stigmas protrude above. This staminal tube joins the united portion of the corolla at its base. Such an arrangement is characteristic of the Malvaceæ.

The ovary is prominent and usually four-celled. The capsule is called the boll; in most cultivated varieties this is somewhat ovoid and is dehiscent at maturity, at which time the white masses of the dried fibers fluff out of the open cavities of the boll, obscuring the seed from view.

The seed of cotton[1] is elongate-ovoid, usually a trifle over 1 cm. long. The hull is brown and crustaceous; the embryo well developed, consisting of radicle, hypocotyl, and a pair of intricately folded cotyledons.

Seeds of most cultivated American cottons possess two kinds of epidermal hairs. The long fibers, which are the cotton of commerce, are known to the cotton trade as LINT. The short hairs, fuzz, or LINTERS, remain after the lint is removed and may be taken off by subsequent processes.

The mature cotton fiber (Fig. 152) is a flattened, twisted, tubular structure. Its walls are nearly pure cellulose, with a slight impregnation of waxy and mineral substances, some of which may be removed in the washing and bleaching processes of textile manufacture. Length, strength, and color of fiber varies in different cottons. Toughness, flattening, and natural twist of fiber are among the most valuable characteristics of cotton.

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[1] See also Chapter XI.

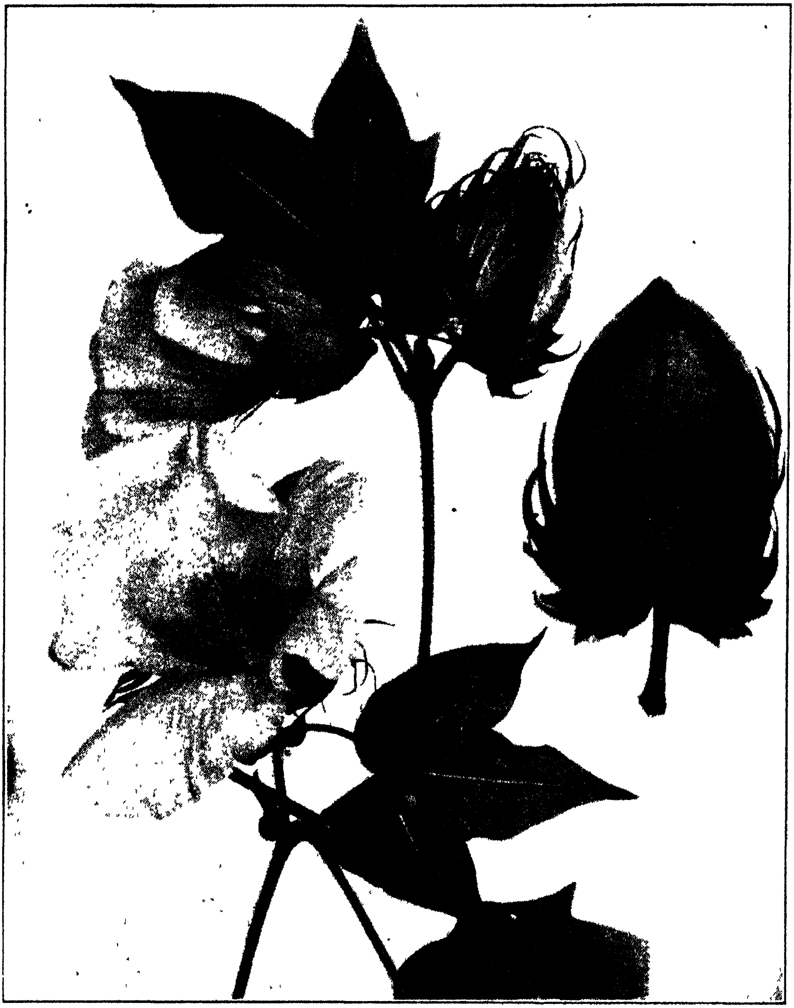

FIG. 151. — Leaves, Flowers, and Full-Grown Green Boll of Upland Cotton. (Courtesy of Bureau of Plant Industry.)

Species and Varieties of Cotton

The commercial cottons (Fig. 153) of to-day result from centuries of selection, hybridization, and adaptation to various climatic and soil conditions in tropical and subtropical regions. As might be expected, species lines are extremely difficult to trace.

SEA ISLAND AND OTHER LONG-STAPLE COTTONS

This group includes the highest qualities and longest staples of all cottons. They are of several races, with fiber lengths varying from 1½ to 2½ inches. As a class, they are of limited geographical distribution. Sea island cotton, usually referred to *Gossypium barbadense*, probably originated either in the West Indies or in South America. Its production in the United States is limited to coastal islands and a coastal area in South Carolina, Georgia, and Florida. For many decades sea island cotton supplied the longest and strongest of American cottons and was scarcely excelled in the world. American sea island cotton culture, unfortunately, has within recent years been almost exterminated by the boll-weevil.

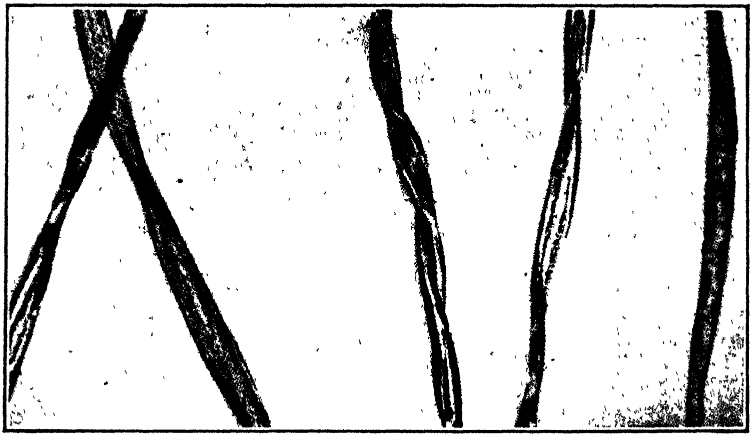

FIG. 152. — American Cotton Fibers. (Reprinted by permission, from *Textile Fibers*, by the late J. Merritt Matthews, published by John Wiley & Sons, Inc.)

Egyptian cotton, a closely related product, is of slightly shorter staple but of extremely high quality. It is one of the most valued crops of the Nile delta. Both brown and white varieties are grown. Peruvian cotton is of similar nature. In recent years both Egyptian and Peruvian types of cotton have been grown with some success in Arizona and California.

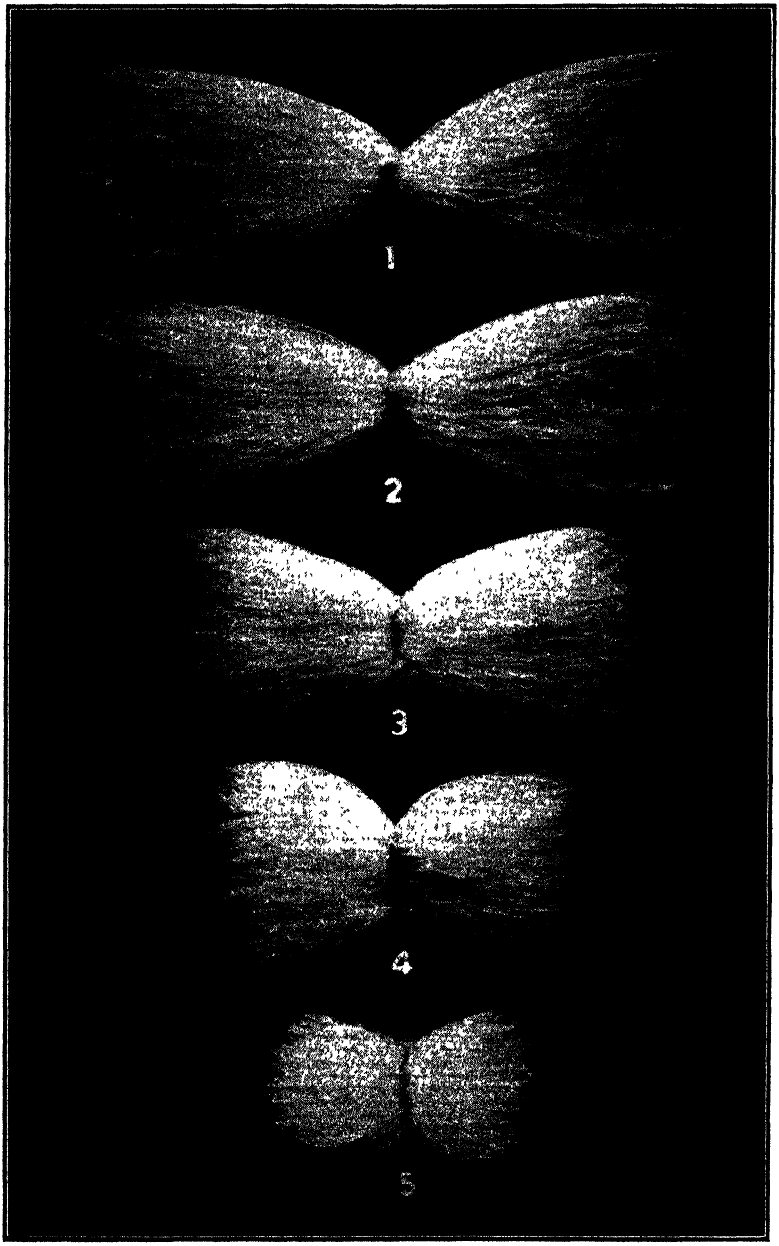

FIG. 153. — Combed Cotton Fiber, on the Seed. (1) Sea Island; (2) Egyptian (Pima); (3) Long Staple Upland; (4) Short Staple Upland; (5) Asiatic. Natural size. (Courtesy of Bureau of Plant Industry.)

UPLAND COTTON

Ninety-five per cent or more of American cotton is of this type. Upland cotton (Fig. 154) embraces manv more or less well-defined groups and a vast number of cotton varieties, most of which are referable to *Gossypium hirsutum* or to hybrids between

Fig. 154. — Upland Cotton Ready for Picking. (Courtesy of Bureau of Plant Industry.)

that species and *G. mexicanum*. Upland cottons are vigorously growing, heavy yielding plants, well adapted to the climatic and cultural conditions of the Old South from the Carolinas south and west to Oklahoma and Texas. Throughout this area cotton was for nearly a century almost the sole crop, a position which it would have held longer, no doubt, save for the depredations of insects and disease. In recent years, a greatly over-supplied world market has been the most potent factor in loosening the hold of "King Cotton" upon the South, and in driving the Cotton Belt toward crop diversification.

Some varieties of upland cotton are known as long-staple, but the fibers of the group average shorter than that of sea island cotton and rarely exceed an inch in length. Quality, also, is inferior to that of the true long-staple cottons. Yield is much larger, and to that and to greater range of soil and climatic adaptability are due the position of American upland cotton as the dominant textile fiber of the world.

OTHER COTTONS

Cotton growing is an important industry in many tropical countries. Indian cotton—a short-staple product, usually of inferior color and quality—is grown in large quantity, and enters European trade, particularly that of Great Britain. There are a number of commercial varieties of Indian cotton, attributed to *G. herbaceum*, *G. obtusifolium*, and *G. Nanking* and their hybrids. Several strains of American upland have in recent years been introduced into India and other tropical countries. The Chinese cotton crop is known to be of great volume, but, like many other products of that region, it enters commerce but little and no statistics of production exist. The annual crop of China has been conjectured to reach 2,000,000 bales. Asiatic Russia and several South American countries are also producers of cotton.

Environmental Relations and Culture

Gossypium species are all of tropical origin, and successful culture is possible only in lands of high temperature and of long growing season—six months or more. In the United States cotton production is chiefly confined to the region (Fig. 155) bounded by the summer isotherm of 77° F. Upland cotton thrives best in deep, well-drained loam but is tolerant of less favorable soil providing the moisture content is suitable and fairly constant. Rain during picking season injures fiber—a fact which gives

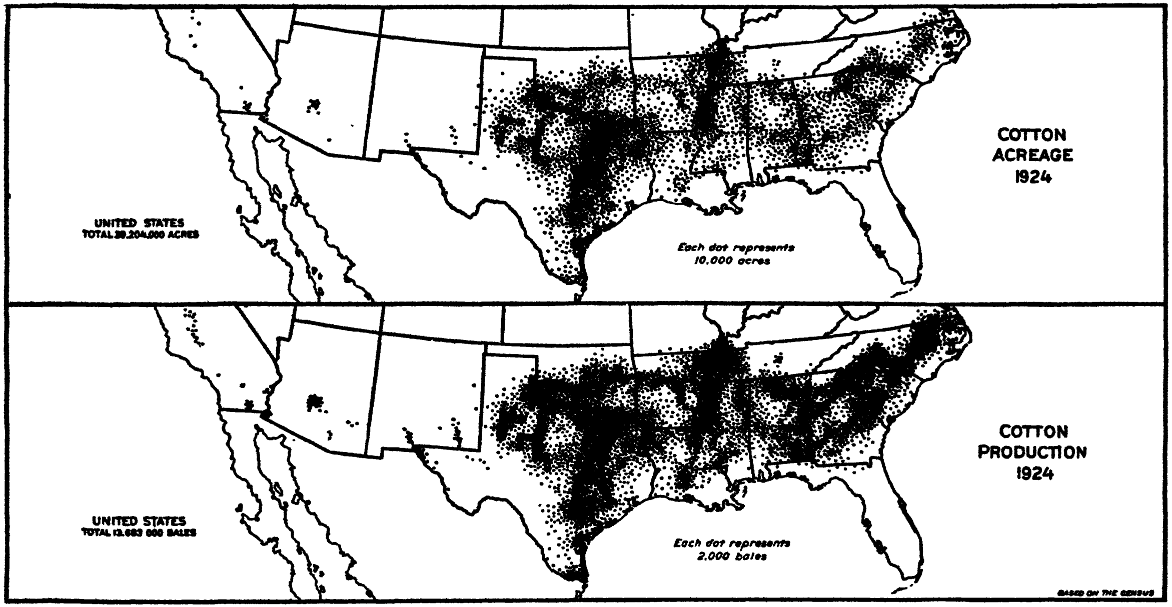

Fig. 155. — Cotton Acreage and Production in the United States, 1924. The northern boundary of the Cotton Belt is approximately the line of 200 days' average frost-free season and 77° mean summer temperature; the southern boundary is that of ten inches autumn rainfall, because wet weather interferes with picking and damages the lint. The western boundary of cotton production without irrigation is approximately the line of twenty inches average annual rainfall. The densest areas on the map are districts of richer soils, notably in Black Prairie of Texas and the Yazoo Delta, or heavily fertilized soils, especially those of the Piedmont and Upper Coastal Plain. (From United States Department of Agriculture *Yearbook*, 1928.)

irrigated lands competitive advantage over the Cotton Belt of the United States, with its somewhat uncertain weather. Clean culture is essential to successful cotton-raising.

Despite the considerable bulk of the cotton crop, it is not exhaustive of the soil. The lint, being nearly pure carbohydrate, takes almost nothing but water from the earth. The cotton plant as a whole, of course, removes potash and other mineral nutrients, and the seed is rich in soil-derived nitrogen. Under the single-cropping system long in vogue in the South, cotton has been raised uninterruptedly on the same land for more than forty years. Cotton land, cropped to apparent exhaustion, is allowed to rest. This, in effect, means abandonment to a miscellaneous growth of weeds, chiefly composites, whose seasonal death and decomposition renews in a few years the depleted humus, after which cotton is again grown. Continuous single-cropping, however, is objectionable from viewpoints other than that of simple soil exhaustion. It favors multiplication of diseases and insect pests, and this has been particularly true in the case of cotton. These facts, and economic disaster which has often followed low cotton price, tend to bring about the introduction of crop rotation in the Cotton Belt.

Cotton blossoms profusely over a considerable period; a large proportion—often more than half—of buds, blooms, and immature bolls are shed before ripening. This boll-shedding is a crop factor of considerable importance; its causes are not well understood. Lack of pollination has been held to be involved, and there is evidence that fluctuations of soil moisture cause abscission.

Lint begins to mature in five to six months after planting; if frosts, which are fatal to the plant, do not interfere, the ripening season may be prolonged for three months or more.

Upon ripening, the bolls dehisce widely, and the lint, with its enveloped seeds, may readily be picked out. Picking (Fig. 156) is almost invariably done by hand; numerous attempts to develop cotton-picking machinery have so far met with little success. Because of the large amount of hand labor involved in culture and picking, cotton is essentially a cheap labor crop. Because of high temperatures of cotton-raising regions, Negro labor dominates the southern cotton field; while Mexicans, Filipinos, and other Orientals are employed in the West. As the work of harvest is relatively light, women and children pick cotton, and in many regions harvest most of the crop. The rapid spread of cotton-growing in the South in early years of the last century led to the concurrent increase of slave labor and the development of the plantation system. Cotton was a main inciting factor, if an indirect one, in the most disastrous war ever fought on the American continent; as a still further balance to the many undoubted values of the crop, its culture has afflicted the nation with some of its gravest sociological problems of race relationship.

FIG. 156. — Cotton Picking in the Yazoo Mississippi Delta. (Courtesy of Bureau of Plant Industry.)

Cotton Ginning

During the ripening period the seeds separate from the placenta; at picking time they are wholly surrounded by a tangled mass of lint. Fiber separation by hand is a most laborious process; the present supremacy of cotton among textiles dates from the invention of the cotton-gin by Eli Whitney in 1793. The SAW GIN still follows the original Whitney principles. After a preliminary cleaning to remove boll-fragments and trash, the cotton is conveyed to the box or hopper of the gin. One side of this is a steel grate, through the narrow openings of which extend thin-notched steel disks, the saws. These rotate rapidly; their teeth catch the fibers and pull them through the grating. Lint is removed from the saws by a rotating brush. Ginned cotton passes out to a condenser, where it is baled, while the cleaned seed drop from the gin-box and are removed by a screw conveyor.

Linters may be removed by another gin, whose saws have finer teeth.

Sea island and other long-staple cottons are ginned by a machine of another type, called a ROLLER GIN. The roller gin cleans more slowly than the saw gin, but is less injurious to long, valuable fiber.

Cotton enters commerce in the BALE, a rectangular pressed mass about twenty-seven inches in the equal dimensions and twice as long, held by wires or hoops and covered with coarse burlap. Bales weigh about 500 pounds apiece. Production of cotton in the United States for a single year has been indicated in Fig. 155. That for a number of recent years is shown in Table IV.

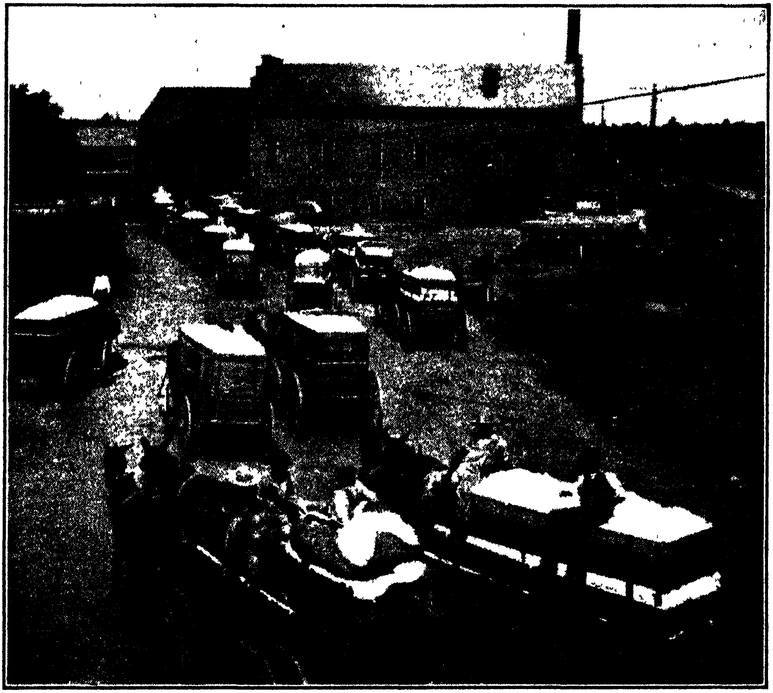

FIG. 157.—Carrying Cotton to the Gin in Georgia. The gin-house is in the background. (Courtesy of Bureau of Plant Industry.)

The Uses of Cotton

Cotton is the great fiber product of the vegetable world and much more than that. It is generally granted to be the most important article of world trade. On cotton are based some of the greatest national manufactures of the United States and of the British Empire. Cotton is the major crop of a large section of our own country, where prosperity and poverty alternate according to yields and prices, vicissitudes of season, boll-weevil destruction, and major and minor world upheavals. In our own Civil War, in the World War, and in British-Indian and Sino-Japanese difficulties, cotton has played rôles more important than can even be indicated here.

Some idea of the importance of cotton in the world-picture may be gained from recent estimates of consumption in various regions. It has been computed that the average American family uses from 110 to 135 pounds of cotton per year; a Western European family, less than 50 pounds; a Russian family, 25 pounds; a Chinese family, less than 10 pounds.

The major uses of cotton, of course, are in the textile industries. Cotton appears frankly as the sole material of some hundreds of recognized fabrics, and mingles also, sometimes, with linens, woolens, silks, rugs, tapestries, and so forth, whose more prominently mentioned constituents are fibers of greater price. That part of the world which rolls on rubber would make little distance save for the sturdy backing of cotton cords that have replaced the more perishable "fabric" of earlier tires. Quantities of unspun cotton and linters are used in mattresses, pads, and upholsteries. For use as absorbent cotton, lint is freed from its coating of waxy material and its fraction of one per cent of mineral matter, by treatment with acids and alkalies, followed by thorough washing. Absorbent cotton should absorb about eighteen times its own weight of water.

As almost pure cellulose, lint and linters are largely used in the cellulose industries. Dissolved and reprecipitated in sheets or threads, they form the cellophane so popular for transparent coverings of confectioneries, foodstuffs, and merchandise of many kinds. Spun into thread by pressure through tiny holes in dies, resolidified cellulose becomes rayon or artificial silk, a commodity of constantly growing importance.

Nitrated celluloses and a series of compounds called cellulose esters form a group of products whose use is also constantly widening. Plastic forms are known as pyroxylins, of which celluloid is a familiar example, although it is less used now than other forms which are not so violently combustible. Explosive nitrocelluloses are used as guncotton and in smokeless powder. Other nitrocelluloses are known as collodion, and by various trade names. Cellulose varnishes and lacquers cover millions of automobiles; they are assuming prominence in furniture finishing and house decoration. These finishes are of rather recent development; in the last few years their increase in use, particularly for automobile surfacing, has been phenomenal. Among qualities which recommend them are applicability to spraying processes; quick drying qualities; and durability, particularly upon metal and under outdoor conditions.

COTTON CLOTHS

Spinning of cotton into thread or yarn was first done by hand. Even to-day, East Indian artificers so produce—and from inferior cotton—gossamerlike threads whose quality is not approached by the highly mechanized spinning of the Occident. Early weaving was by hand looms. At present, both spinning and weaving are among the most technical of industries, conducted, in America, Europe, and to some extent in Asia, in great mills whose plant and machinery values are measured in millions of dollars. The development of the cotton manufacturing industry in the last century and a half is a marvelous example of coördination of technical ingenuity and financial genius. As in many other highly mechanized industries, the progress of cotton spinning and weaving has been a history of continual replacement of human labor by highly efficient mechanical contrivances; the problem of maintaining purchasing power of the displaced masses of humanity is yet to be solved.

The highest developments of cotton manufacturing are those of the Lancashire district in England; those of New England; and, in recent years, those of the Carolinas. While not inconsiderable, cotton manufacturing in other European countries is still dwarfed by the industries of Great Britain and the United States. Strenuous efforts to foster it have been made by various nations; cotton manufacture has entered into the industrial development of Japan, and into the Five Year Plan in Russia. From India, Gandhi with his hand spinning-wheel rises as a world figure. Boycott of Japanese cottons in China has been a major factor in the troubled relations between the two principal Oriental nations.

The Cotton Crop of the World

Cotton is the main textile fiber, not only of the United States, but of the entire world. Probably more cotton is produced annually than all other fibers combined. As in the case of many an-

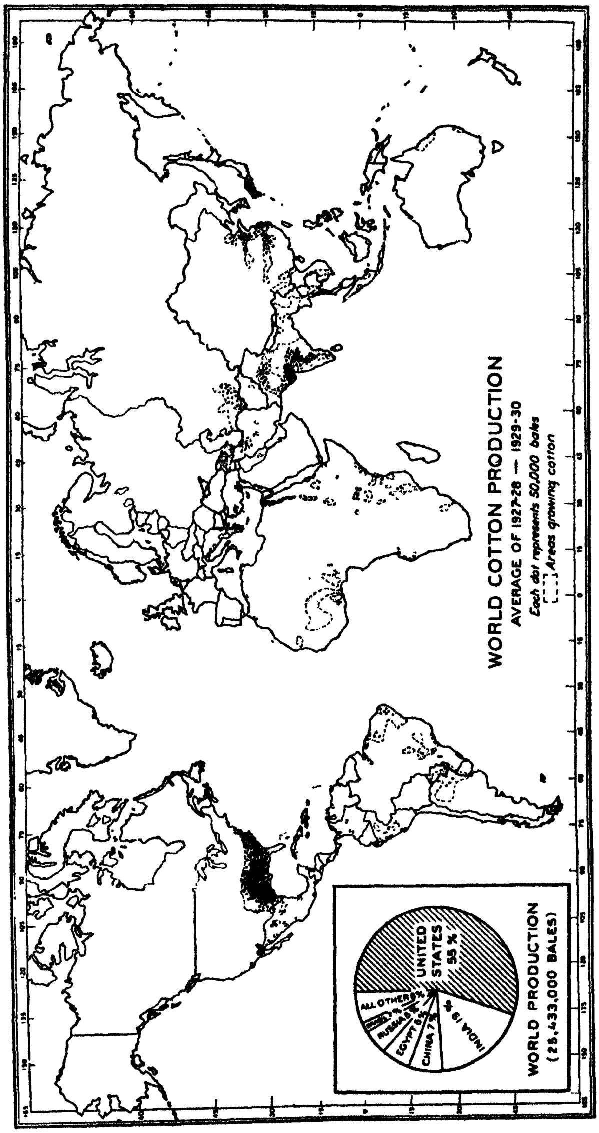

FIG. 158. — World Cotton Production, for Years Stated. (Courtesy Bureau of Agricultural Economics, United States Department of Agriculture.)

other great staple, the recent years (1929–1933) have seen unprofitable overproduction—at least as judged by demands, though consumption for those years could hardly be called normal.

TABLE IV

COTTON: WORLD PRODUCTION OF LINT, PER YEARS STATED IN THOUSANDS OF BALES

CROP YEAR	*Estimated world total excluding China* *1,000 bales* [3]	*Estimated world total including China* *1,000 bales* [3]	PRODUCTION IN SELECTED COUNTRIES						*Estimated world total commercial crop* [2] *1,000 bales* [4]
			United States *1,000 bales* [3]	*India* *1,000 bales* [3]	*Egypt* *1,000 bales* [3]	*China* [1] *1,000 bales* [3]	*Brazil* *1,000 bales* [3]	*Russia* *1,000 bales* [3]	
1909–10	16,900	....	10,005	3,998	1,036	......	324	......	[5] 16,241
1910–11	18,400	....	11,609	3,254	1,555	.....	357	......	[5] 18,027
1911–12	21,900	....	15,693	2,730	1,530	......	360	......	[5] 21,269
1912–13	21,100	....	13,703	3,702	1,554	......	418	......	[5] 20,976
1913–14	22,200	....	14,156	4,239	1,588	.....	477	....	[5] 21,618
1914–15	24,200	....	16,135	4,359	1,337	.....	465	1,270	[5] 23,768
1915–16	17,800	... ...	11,192	3,128	989	......	339	1,512	[5] 17,649
1916–17	18,366	19,900	11,450	3,759	1,048	1,534	337	1,199	[5] 18,092
1917–18	17,608	19,700	11,302	3,393	1,304	2,092	414	634	[3] 18,140
1918–19	17,841	20,900	12,041	3,328	999	3,059	406	161	[3] 18,755
1919–20	18,782	21,300	11,421	4,853	1,155	2,518	461	81	[3] 20,220
1920–21	19,217	21,100	13,440	3,013	1,251	1,883	476	58	[3] 19,665
1921–22	13,886	15,400	7,954	3,753	902	1,514	504	43	[3] 15,334
1922–23	16,982	19,300	9,755	4,247	1,391	2,318	553	55	17,926
1923–24	17,707	19,700	10,140	4,320	1,353	1,993	576	196	19,036
1924–25	22,622	24,800	13,628	5,095	1,507	2,178	605	453	23,836
1925–26	25,798	27,900	16,104	5,201	1,629	2,192	602	782	26,678
1926–27	26,658	28,400	17,977	4,205	1,586	1,742	512	830	27,819
1927–28	22,125	24,000	12,955	4,990	1,261	1,875	487	994	23,426
1928–29	24,434	26,900	14,478	4,838	1,672	2,466	525	1,174	25,628
1929–30	24,384	26,500	14,828	4,289	1,768	2,116	584	1,279	26,653
1930–31	23,550	25,800	13,932	4,372	1,715	2,250	470	1,589	25,304
1931–32	25,800	27,500	17,096	3,401	1,288	1,700	570	1,851	26,329
1932–33 [6]	21,700	24,000	12,994	3,900	950	2,300	348	1,950	.. ....

From *United States Department of Agriculture Yearbook*, 1933. Bureau of Agricultural Economics. Compiled from official sources and International Institute of Agriculture unless otherwise stated. The crop year is from Aug. 1 to July 31. For the United States prior to 1914 the figures apply to the year beginning Sept. 1.

[1] Chinese Cotton Mill Owners' Association, except for 1930–31 to 1932–33, which are estimates of the Bureau of Agricultural Economics. Figures represent the crop in the most important cotton-producing Provinces where the commercial crop is grown. Most of the cotton produced in other Provinces is used for home hand-loom consumption.

[2] Figures as reported by the U. S. Bureau of the Census, including the cotton destined to enter commercial channels for factory purposes. Estimates of the commercial crop in China are included.

[3] Bales of 478 pounds net.

[4] American in running bales and foreign cotton in bales of 478 pounds net.

[5] Bales of 500 pounds net.

[6] Preliminary.

[7] Approximate, mid-point of range of reports.

The principal regions of cotton production have already been noted. Fig. 158 indicates estimated world production for an average of two recent years, and Table IV presents a statistical summary for a longer period.

COTTON CROP REGULATION

Any adequate account of the position of the cotton crop in the economic life of the world would require space far beyond the possibilities of this volume. In the United States alone over 2,000,000 families—some 10,000,000 people—are directly engaged in the raising of cotton, and perhaps 2,000,000 more persons are engaged in its handling, ginning, shipping, etc. The United States produces more than half the world's cotton crop. As over half the yield of the Cotton Belt is sold abroad, the southern cotton-farmer is directly exposed to the effects of wars, currency fluctuation, crop-stimulation elsewhere—to any major upheaval of the economic life of the world. In 1919, cotton sold on the farm for 35.6 cents per pound; in 1920, for 13.9 cents. From 19.6 cents in 1927, it fell steadily to 5.7 cents in 1931. Even under what are considered good conditions, the income of a cotton-raising family is less than $500 per year—and that is reckoned in credit rather than cash! In 1932–1933 it was less than $240. The possibility of maintenance of an "American" standard of living under such conditions requires no comment.

Cotton was among the first of great crop-commodities selected for governmental control during 1933. About one fourth of a cotton crop of 41,000,000 acres was plowed under, and growers were compensated by the federal government at an average price of $6.50 per acre. To meet the cost of this bonus, a processing tax was imposed upon cotton consumed in this country.

Despite acreage reduction, the cotton crop was practically the same as that of the preceding year. Cotton in 1933, nevertheless, sold above 11 cents per pound. Farm-family income rose to about $375.

For 1934-1935, a more elaborate plan of control has been devised. It is intended to restrict the American cotton crop to 25,000,000 acres, and upon the 15,000,000 odd acres vacated to induce the planting of crops for home consumption rather than crops for sale. Reimbursements for lost cotton-acres will continue to be effected through a processing tax, which is expected to be between 4.3 cents and 4.5 cents per pound of cotton used in America. It has been estimated that the average American cotton-consuming family will pay the average American cotton-producing family a bonus of about $4.50 for the year.

The world cotton crop for 1933 increased over the preceding year. In other producing countries—Egypt, India, China, Russia, and Brazil—production and living costs are far below those of the cotton-raising South, and acreage in these regions tends to increase as our decreases. While the world-price of cotton has advanced, the American dollar has dropped, and in terms of their own currencies consuming nations of Europe have paid scarcely more for American cotton than in the period of its lowest price.

At the time at which this is written, it is quite impossible to predict the future of the American cotton crop. It seems quite probable that the foreign market will be supplied to an increasing extent by the produce of the tropics, and that, unless it be kept out by a high tariff wall, cotton of other lands will compete for our own industrial demands. If American cotton is eventually to be confined to domestic use, profound readjustment of the whole agricultural life of the South and of the economic life of the nation must result. If, in face of all these conditions, and of many more that cannot even be mentioned in the present connection, life in the Cotton Belt is to approach what we like to consider the "American scale of living," it will necessitate a series of planned changes in agricultural and industrial life, not only in the South but through the whole country, far beyond anything designed in the past by this or any other nation. And the cotton problem is only one—if perhaps the greatest—of the farm-life problems which confront the present generation.

3. THE SOFT FIBERS

From point of view of plant origin as an epidermal hair, cotton is in a class by itself. Other important textile fibers are commonly grouped as SOFT FIBERS and HARD FIBERS. The designations refer, essentially, to size and stiffness; and these characteristics are due, in their turn, to cellular structure and composition. The soft fibers are those found in groups in barks of dicotyledons; cellulose is their principal constituent, although some—such as jute—are somewhat lignified. The chief hard fibers are composed of woody sclerenchymatic elements and are found in association with vascular bundles, in wirelike strands close to the outer tissues in leaves and leaf-bases of massive tropical monocotyledons.

Flax

THE FLAX PLANT

Flax is perhaps the oldest textile plant of human use. The fiber of commerce is obtained from a slender annual, *Linum usitatissimum* (Fig. 159), indigenous to Europe, and a member of the small family Linaceæ. Other species of this genus yield fibers, but are now unimportant. *L. angustifolium,* a perennial, was cultivated by Swiss lake-dwellers of the Neolithic period. The mummy-cloth of ancient Egyptians appears to be of linen; flax culture and preparation of fiber are depicted on Egyptian walls and tombs. American Indians used another perennial species, *L. Lewisii,* for coarse fabrics and fish-nets.

Numerous varieties of *Linum usitatissimum* are in cultivation to-day. Flaxseed, produced from bushy varieties lacking in fiber value, is noted in Chapter XI. Fiber flax varieties are slender, branching a little toward the top, attaining a height of about forty inches. Leaves are narrow, ovate-lanceolate, and sessile. Flowers are generally of delicate blue, sometimes white, and very regular of structure. They open briefly; usually, apparently, they are self-fertilized. The seed pod, or boll, is somewhat less than a half inch in diameter, five-carpelled, and nearly or quite indehiscent.

Culture of Fiber Flax.—Fiber flax is chiefly grown in northern humid regions of short summers. Before the extensive exploitation of cotton following the development of the cotton-gin, flax was grown everywhere throughout the temperate zones of Europe and in the settled portions of North America. In recent years flax production has become a decidedly localized industry, centering in Russia—which before the World War afforded 80 to 85 per cent of the world's supply—in Belgium and in Ireland. Flax production has been taken up actively in northern Japan. In the United States, cultivation has persisted in a limited way in Michigan, and rather recently has been attempted in Oregon, where the fiber is processed by inmates of the State penitentiary. As the United States is the largest world market for linen goods, it would appear that successful development of flax culture here depends chiefly on development of labor-saving machinery.

Flax is grown to advantage in cool regions of considerable humidity. Well-drained loam is desirable soil, and fertilization is usually essential, although the crop is less soil-exhaustive than has usually been believed. Flax is rather subject to fungus dis-

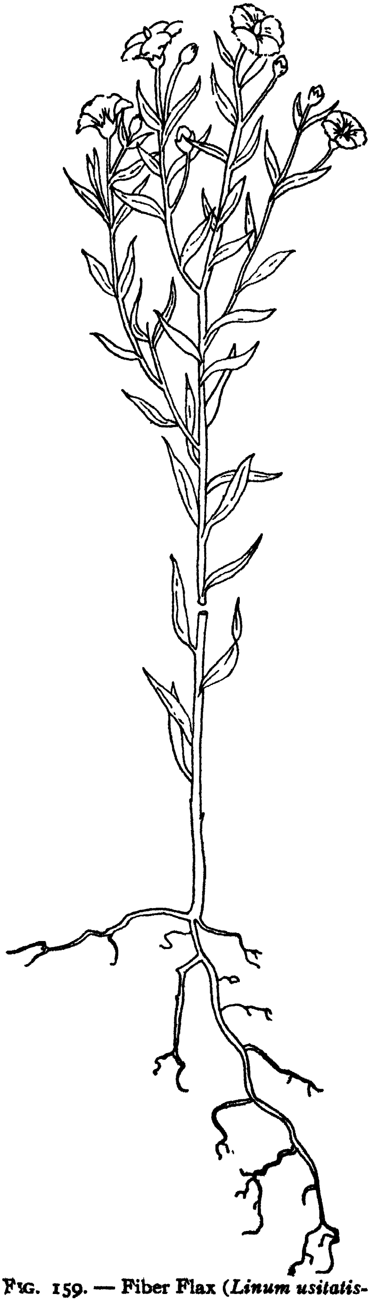

Fig. 159. — Fiber Flax (*Linum usitatissimum*). (E. Coffman.)

ease, and rotation is advisable. The season is from 70 to 100 days. Yield of fiber is from 200 to 450 pounds per acre.

THE FLAX FIBER

Flax fiber is a typical bast fiber, being situated in the central region of the bark (Fig. 160). It is prepared for spinning by a series of processes which, as usually carried out, involve much hand labor. Introduction of machine processes has been attempted in a small way in the United States.

The sowing and field-handling of flax are comparable to that of field grains. Harvest may be either in the green-ripe or yellow-ripe stage. The former is soon after full bloom. Irish flax, and some of the flax of Western Europe, is harvested green-ripe. The fiber is then easily separated and very fine, but no seed is obtained. In the yellow-ripe stage the plant begins to turn yellow and the leaves to fall. Most American flax is pulled late yellow-ripe, in order to obtain the seed as well as the fiber. Somewhat immature seed will ripen in the shock. Yellow-ripe flax yields coarser and stronger fiber than the green-ripe. At a fully mature stage, the fiber becomes somewhat lignified, difficult to separate, and of inferior spinning quality.

Flax is usually harvested

by pulling (Fig. 161), a back-breaking process when done by hand. The slender plants are bound in small bundles and dried in the field. Dried flax is RIPPLED or threshed in order to get rid of leaves and bolls with the least possible breakage of stem and injury to fiber. Rippling, as done in Europe, consists in drawing

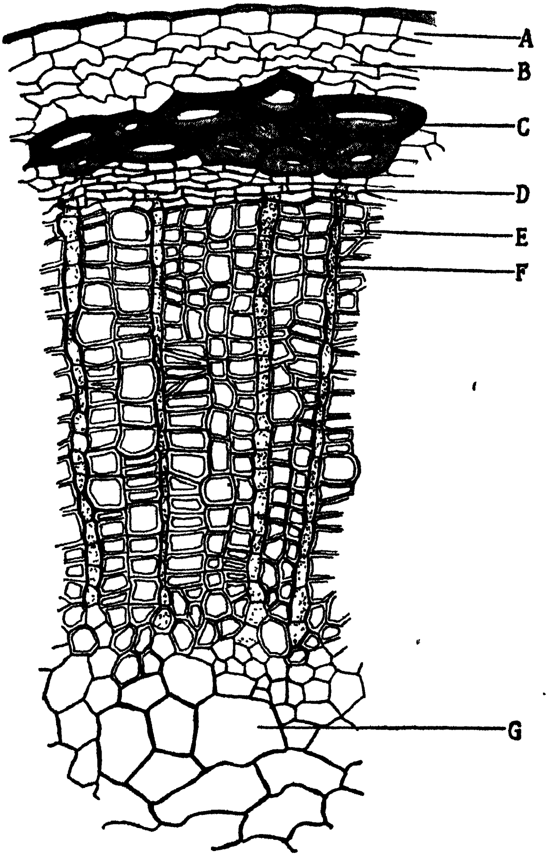

FIG. 160. — Portion of a Flax Stem in Cross-Section. *A*, epidermis; *B*, cortex; *C*, fibers; *D*, cambium and phloem; *E*, wood; *F*, ray; *G*, pith. (H. McCarthy.)

the bundled flax through a comblike device. In the United States the bundle-heads are passed between two revolving pulleys held together by springs.

Separation of fiber from straw involves RETTING. This is essentially a fermentation in which the action of bacterial enzymes partially disintegrates the cementing intercellular layer, after which the fibrous aggregates may be combed free of wood and bark elements. In dew retting, as in Michigan and Russia, the straw is spread in the field and exposed to the moistening of dew, rain, and snow from two to eight weeks. Water retting—carried out in Ireland, Belgium, some portions of Russia, and in Oregon—is a more rapid process. It yields a better fiber, but involves more hand labor. Flax bundles are weighted upright in pools, reservoirs, or tanks, and allowed to remain there from one to two weeks, depending upon water conditions, particularly temperature. The process must be carefully watched and controlled. At the proper stage of decomposition, the bundles are drained and dried.

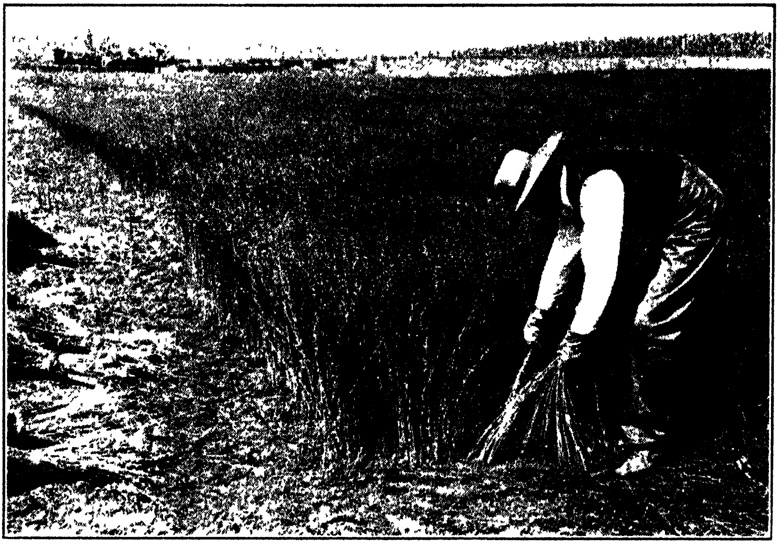

FIG. 161. — Pulling Flax by Hand. In order to obtain fiber of high quality flax must be pulled and not cut. This laborious hand work is now being superseded by flax-pulling machines. (Courtesy of Bureau of Plant Industry.)

Apparently several forms of bacteria are concerned in the retting process, particularly anaërobic species which act upon the pectins of the intercellular layer. Anaërobic action is made possible by presence of various aërobic bacteria and fungi. Experimental use has been made of pure cultures in the retting process. Use of warm water accelerates bacterial action; this is done in Oregon and to some extent in Belgium.

Woody material and other cellular debris is removed by **BREAKING, SCUTCHING,** and **HACKLING.** Breaking is accomplished by passing the dried, retted straw between fluted rollers (Fig. 162). The woody portions thus shattered are removed by scutching—the beating action of a paddle-wheel-like device. Combined breaking and scutching machines are in use in the United States. Hackling is a combing operation by which the fiber is further freed from other matters and straightened, either by hand or by machinery. Fully hackled flax is called dressed line; it is used in threads and the better grade flax fabrics. Short and tangled fibers discarded in hackling make up tow. Tow is used in flax yarns and in cheaper and coarser fabrics such as canvas and crash. Flax upholstery tow, used in stuffing furniture and in insulating refrigerator cars, is made by merely crushing unretted straw of seed flax and poor grades of fiber flax.

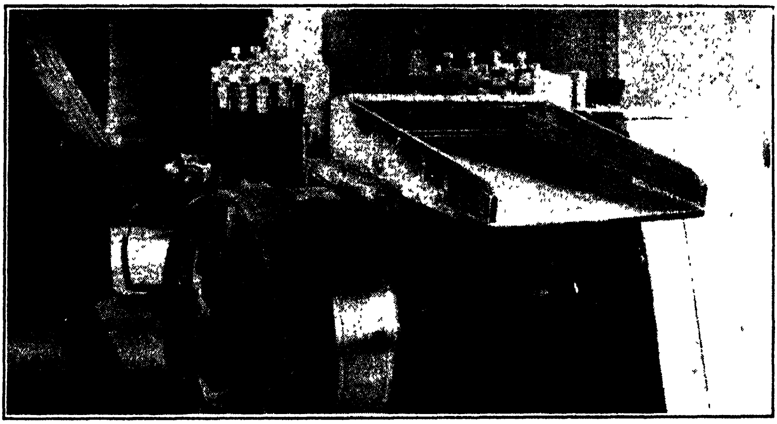

Fig. 162. — A Flax Brake. The retted flax straw passes endwise between the four pairs of fluted rollers, breaking the woody interior part into small pieces, which are removed in a scutching machine. Machines of this type are being replaced by more modern and efficient breaking and scutching machines. (Courtesy of Bureau of Plant Industry.)

The Nature of Flax Fiber.—While cotton fiber is single-cellular, the strands of flax and other bast fibers are aggregates of many cells. The material is nearly pure cellulose, becoming slightly lignified only if allowed to over-mature before harvest. The cells (Fig. 163) are thick-walled, with small narrow lumen; quite uniform in surface, with faint nodular markings which are more apparent when the fiber is treated with dissolving agents. Cells range from 12 to 25 microns in diameter and from 25 to 30 mm. in length. Even after retting, the cells remain rather firmly attached to each other by the mucilaginous intercellular layers; good flax strands average twenty inches in length. The fibers have a small amount of oily and waxy infiltration, whose presence is an aid to spinning.

Flax has a fine luster; water-retted fiber is pale yellow; dew-retted, grayish. The material bleaches readily, but loses strength in the process. Flax is much stronger and stiffer than cotton; like most other fibrous cellulose substances, it is considerably stronger when wet than when dry.

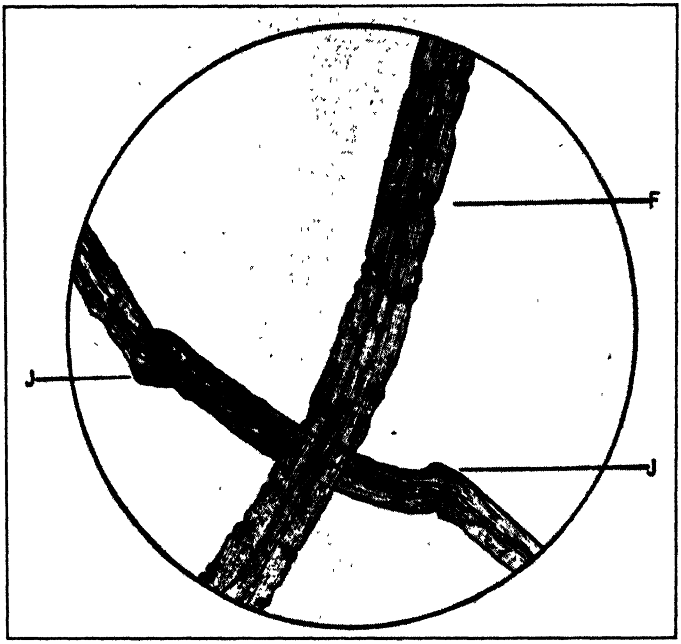

FIG. 163. — Flax Fiber, Stained with Methyl Violet. *F*, fissurelike markings; *J*, jointlike formations. (Reprinted by permission, from *Textile Fibers*, by the late J. Merritt Matthews, published by John Wiley & Sons, Inc.)

USES OF FLAX

Flax fabrics are known as linens. Cambric and damask are among the finer linens. Laces are high grade products, the best being intricately worked by hand. Coarser fabrics include the crashes used in towelings, linen canvas, etc. Heavy-woven linen is used in fire-hose. Linen yarns, threads, and twines are especially strong, being used in sewing shoes and in the making of fishing-lines and fishing-nets. For ordinary cordage use, flax has been almost wholly replaced by cheaper fibers.

Flax conducts heat better than cotton; garments made from it are among the coolest of fabrics and are especially popular in torrid climates.

Pre-war world production of flax fiber has been estimated at some 2,000,000,000 pounds; output for recent years has been somewhat less.

Ireland is the world's center of linen manufacture, possessing about one-third of all flax spindles. While flax fiber is much grown in Ireland, a great deal of Irish linen is made from imported line. Belgium is also an important flax-manufacturing nation.

The United States imports annually about $3,000,000 worth of flax fiber and $40,000,000 worth of linen goods. Only some of the coarser flax fabrics are made in this country.

The use of linen and flax wastes in paper is discussed elsewhere (Chapter VIII).

Hemp

The term HEMP has been rather loosely applied to a number of strong, coarse plant fibers and the species producing them. Properly it belongs to *Cannabis sativa,* an Asiatic plant of the Cannabinaceæ. This small family is by some authorities united with the Moraceæ.

Cannabis sativa (Fig. 164) is a tall, hollow-stemmed annual from six to sixteen feet in height; Chinese varieties surpass even that. Hemp branches freely in the open, but when thickly sown as for fabric use is usually single-stemmed and slender. Leaves are dark green, palmately compound, commonly with seven serrate leaflets. The plant is diœcious; the flowers small. Staminate flowers are borne in axillary panicles; the pollen is wind-blown. Pistillate blooms are sessile and crowded in dense, spikelike aggregations near branch-endings. Staminate plants die after shedding their pollen, while pistillate ones live for about two months as the fruit matures. Fruit is a small, nearly spherical achene, the hemp "seed" of commerce. It yields a valuable expressed oil. In the Orient, narcotic preparations made from the dried pistillate tops are called *hasheesh, bhang,* and by various other vernacular names. Mexicans prepare *marihuana,* of similar properties. In some parts of the United States where *marihuana* is known, its manufacture and possession is forbidden.

Culture of Fiber Hemp.—As a fiber plant, hemp is of considerable antiquity in China. It seems to have been introduced to Europe by the Scythians about 1500 B.C., although apparently the Greeks and Romans made little use of it before the Christian era. Like flax, it was early introduced into the United States, but has never been extensively cultivated. Kentucky has been the principal American center of hemp growth; at present, Wisconsin leads.

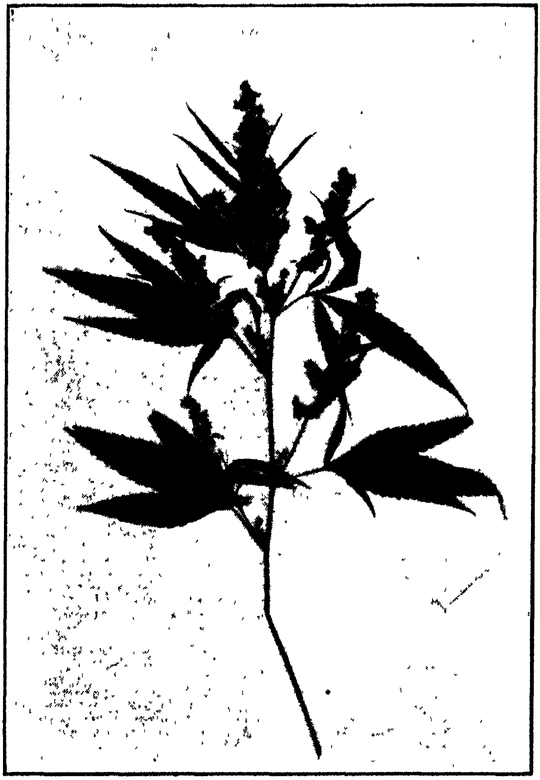

FIG. 164. — Hemp (*Cannabis sativa*); a Branch of a Staminate Plant. (Courtesy of Bureau of Plant Industry.)

For fiber production, hemp does better in a temperate or warm humid climate with at least four months frost free. Growth of seed requires about a month and a half longer. Rich moist loams with good natural drainage yield the best crops. Hemp is more frost-resistant than corn, but drought during the growing season may be disastrous. Growth of hemp is said to improve the soil; while the plant requires abundant plant food, most of this may be returned to the ground after the fiber is secured. Because of its rapid growth and dense shade hemp has been advocated as an eradicator of perennial weeds such as Canada thistle and quack grass. It is not often seriously injured by insects or fungi.

Hemp seed is sown broadcast or in drills. The rapid growth soon covers the soil, and weeding is unnecessary. Harvesting is done when the staminate plants are in full flower. Earlier cuttings yield a fine and soft but weak fiber. As the plant nears maturity, the fiber becomes coarser and less pliable, and the stalks woody and hard to ret. Cutting is by hand or machine, and the crop is dried in shocks.

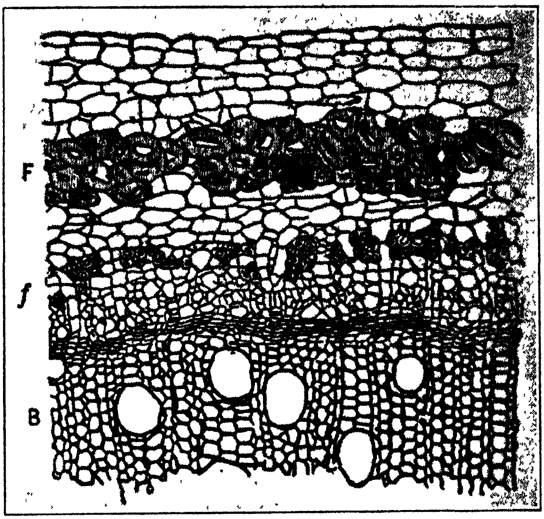

FIG. 165. — Part of Cross-Section of Hemp Stalk. *B*, woody tissue; *F*, main layer of fibers; *f*, secondary layer of fibers. (Reprinted by permission, from Le Comte in *Textile Fibers*, by the late J. Merritt Matthews, published by John Wiley & Sons, Inc.)

Preparation of the Fiber.—Hemp, like flax, is a bast fiber, and similarly located in the stem (Fig. 165). Both primary and smaller secondary fibers occur; hemp line is chiefly primary, while tow includes the secondary fiber. Separation processes (Fig. 166) are similar to those of flax; the plants, of course, are much larger, and machinery has been used more generally than for the smaller crop. Profitable use of machine requires rather large-scale production—units of fifty acres or more. Dew retting is usually practised in the United States; there is considerable hazard from too much rain. Water retting is done in Europe, and a steam process has been employed in Japan.

Hemp fiber production ranges from 400 to 2,500 pounds per acre; 1,000 pounds is considered a good average. About three fourths of this is line, or best grade fiber; the rest is tow.

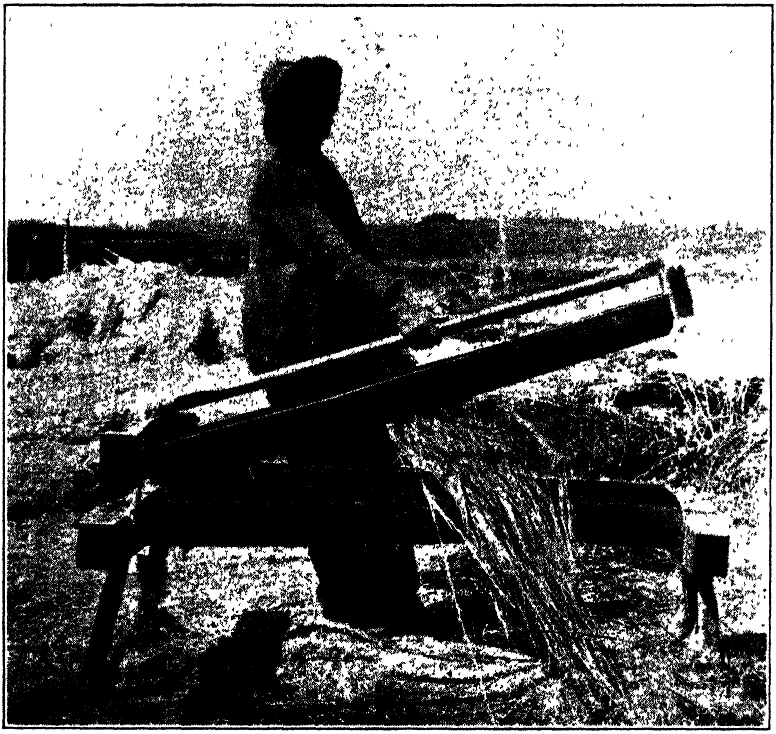

FIG. 166. — Breaking Hemp on a Hand Brake. The woody interior portions of the retted hemp stalks are broken into small pieces called hurds, and these are removed by whipping the fiber across the brake handle. This device of more than a century is being replaced by power-driven machinery. (Courtesy of Bureau of Plant Industry.)

Uses.—Hemp is coarser, harsher, and less pliable than flax. It is very strong, and formerly was extensively used in ropes and ship-riggings, for which purpose it has been largely replaced by abacá. It is still used for twine and cordage; in carpet warp, sail-cloth, tarpaulin, and belt-webbing; and for various other purposes which call for strength and durability and in which dark color is not objectionable. Hemp is not readily bleached.

Hemp tow is used as oakum for packing pumps, engines, etc., and for marine purposes; also in upholstery stuffing. Hemp hurds—the woody parts of the stalks—and hemp wastes are used in paper.

Pre-war production of hemp fiber is estimated at about 1,212,000,000 pounds per year, of which Russia produced about 60 per cent and Italy and Hungary nearly all the rest. American production has probably never reached 1 per cent of the total. The crop of 1927, a post-war year, was about 1,622,000,000 pounds. In that year, American imports were somewhat under 4,000,000 pounds, of which 97 per cent came from Italy. American production of hemp fiber is estimated at from 2,000,000 to 2,200,000 pounds annually. In recent years the use of hemp has been considerably curtailed by the cheaper fibers of jute, abacá, and sisal.

Jute

Jute is a fiber obtained from several species of *Corchorus*, of the Tiliaceæ, grown in India. Of these the chief is *C. capsularis*, India Jute (Fig. 167*A*). Desi or Daisee Jute, *C. olitorius* (Fig. 167*B*), is less extensively grown; other species are unimportant. So-called Chinese Jute is from *Abutilon avicennæ*, of the Malvaceæ; it is an excellent fiber rarely seen in America.

Corchorus capsularis is a woody, little-branched annual, ten to twelve feet in height. The light green leaves are ovate, serrate-margined with peculiar curved bristles near the base. Flowers are small, yellowish white, the seed-pods globular with small brown seeds. Desi jute differs chiefly in its elongate beaked pod, with bluish seeds.

Cultivation of Jute.—Jute has been grown experimentally in the United States, in Europe, and in various other regions, but has wholly failed to establish itself outside India as a commercial crop.

India jute is grown mostly in the river valleys of Bengal in rich alluvial soil which is often overflowed at high water. Desi jute is of higher lands, in Bengal and in Orissa and Bihar. The annual jute crop covers 2,000,000 to 3,000,000 acres. Land is worked by hand, not less thoroughly than the best market gardens of the United States, and the crop is weeded and cut or pulled by hand. Harvest is at flowering time, four or five months after planting.

The Fiber and its Preparation.—After removal of roots and tops, the stems are bundled and retted from ten to twenty days in artificial pools or slow-running streams. They are sunk by weights but not allowed to touch bottom, and they are shaded from the sun by straw. When the bark will slip easily from the wood, *ryots* (laborers) wade into the waist-deep water, break the stalks with mallets, and thresh them on the surface of the water; they rinse, and wring until non-fibrous portions are beaten out, after which the fiber is dried on bushes or poles on the bank.

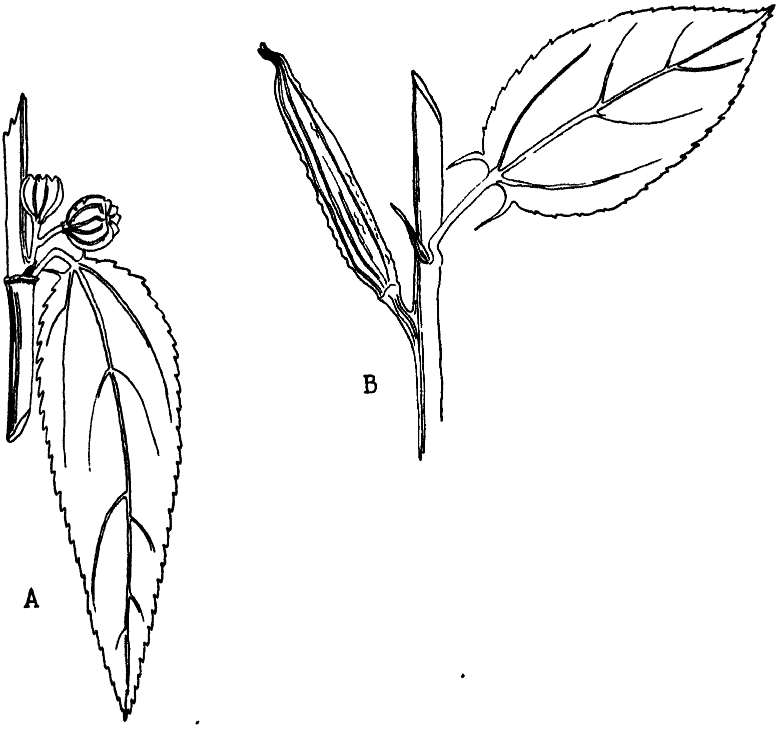

FIG. 167. — Jute: (*A*) *Corchorus capsularis;* (*B*) *C. olitorius.* (E. Coffman.)

The inferior lower ends—jute butts—are cut off; they sell at a lower price. An acre of jute yields about 1,200 pounds of fiber, and a man can separate seventy pounds in a ten-hour day.

Jute fiber (Figs. 47, *A*, *B*, and 168) is yellowish-white, with a fine silklike luster. When retted in muddy water, it takes on a grayish tinge. Unlike flax and hemp, it is considerably lignified. Jute is soft and relatively weak. It is made more flexible in preparation for spinning by treatment with water and oil.

Uses of Jute.—Jute is of rather recent introduction to Europe and North America. Its principal development here has come within the last hundred years. At present it is the cheapest of common textile fibers and is second only to cotton in quantity produced. India's average annual output of raw jute has been estimated at about 3,200,000,000 pounds.

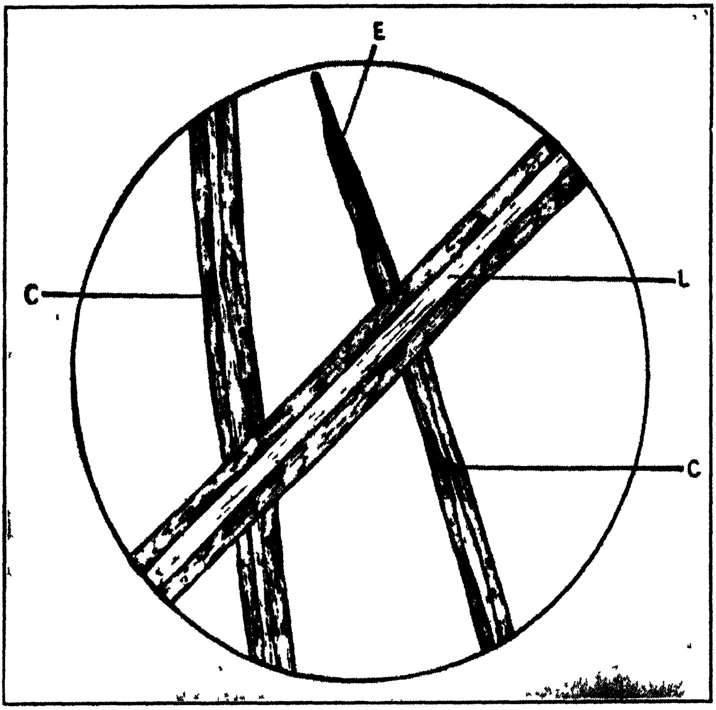

FIG. 168. — Jute Fiber: *L*, cell cavity of lumen; *C*, constrictions in lumen, *E*, end of cell. (Reprinted by permission, from *Textile Fibers*, by the late J. Merritt Matthews, published by John Wiley & Sons, Inc.)

Jute is the world's leading bagging and wrapping textile. Burlap, from which gunny sacks, potato sacks, etc., are made, is the chief jute cloth. Burlap also is employed as linoleum backing. Several other grades of jute bagging are distinguished; coarsest is cotton bagging, with which cotton bales are wrapped; this is made mostly of jute butts. Jute is also used in tarpaulins and carpets. It is the principal fiber used in cheap brown twines, but it is inferior to sisal and henequen for binder twines.

The chief deficiencies of jute are brittleness, lack of durability, and tendency to deteriorate when wet. Ordinary bleaching processes are destructive to it, and traces of mineral acids destroy its fabric.

About 90,000,000 yards of cotton bagging are annually needed to bale America's cotton crop. This is chiefly made in the United States, whereas burlap is mostly imported. British India ranks first in burlap-making. Dundee, Scotland, is second to Calcutta in jute manufactures and leads in export of yarn and cordage.

About 174,000,000 pounds of jute fiber and butts, and 574,000,000 pounds of burlap are imported annually.

Ramie

Boehmeria nivea (Fig. 169), of the Urticaceæ, is a perennial Asiatic plant producing annually from two to four crops of canes three to seven feet high, with thick round or cordate leaves which are green above and woolly white below. On the Asian continent, and probably in Egypt, ramie has been used since primitive times. It is mostly grown in China and Formosa, less commonly in Japan and India. Even in Asiatic use it has largely been replaced by cotton, but it is still extensively employed in China. Rather recently the subject of ramie was brought into prominence by that school of thought called technocracy. Rather startling claims as to its productivity and values were made, including the prediction that it is destined to supplant cotton as a world textile crop, with consequent disaster to cotton growers and the cotton industries.

Ramie is a strong but rather inelastic fiber, deficient in resistance to twisting strains. The principal obstacle to its large-scale use is the difficulty of cleaning the fiber, which is surrounded by very resistant gum. In the Orient, the outer bark is scraped off with a bamboo or bone knife against a bamboo thimble which covers the operator's thumb. Dried strips of fiber thus prepared are known as "China grass." Fiber is made from this by repeated washing in water and drying in the sun—a tedious process. Small quantities of ramie thus far used in European and American textile manufacture have generally been imported as "China grass" and degummed by treatment with acids or akalis, chemicals which usually injure the strength of the fiber.

Repeated efforts have been made, both in America and Europe, to devise practical decorticating and degumming machines but thus far without commercial success. Very recently experiments in Louisiana are reported to have yielded a successful degumming process in which the reagents used are dilute ammonium hydroxide and sodium sulphite.

Under favorable conditions of American cultivation, ramie is stated to yield about a ton per acre of fiber. Yields in the Orient, where the plant is grown on a kitchen-garden rather than field scale, afford from 400 to 700 pounds.

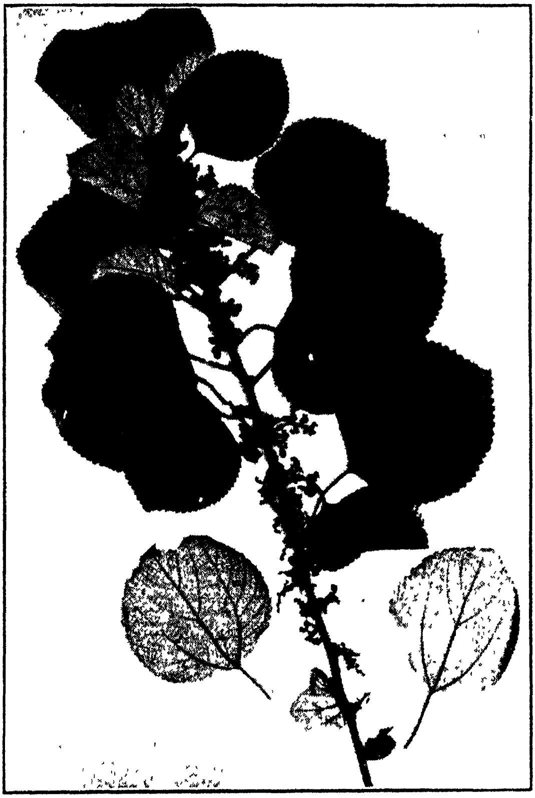

FIG. 169. — Herbarium Specimen of Ramie (*Boehmeria nivea*).

A reasonably cheap process of decortication and degumming might very probably result in a much wider use of ramie, but the quality of the fiber is such that it would hardly be a complete substitute for either cotton or linen. Its commercial introduction to American textile industry is scarcely likely to bring about a revolution, industrial or otherwise

FIG. 170. — Abacá or Manila Hemp (*Musa textilis*). (Photo from Philippine Bureau of Science.)

Ramie fibers average about twice the diameter of linen fibers; they are extremely resistant to a "straight pull" but do not stand twisting well. They "cling" poorly, and yarn spun from them has a fuzzy character, unsuitable for smooth fabrics or for such important uses as automobile tires, belting, etc. It is possible that these qualities may be improved by selection and breeding of superior strains of ramie and by chemical treatment comparable to the mercerization of cotton.

4. THE HARD FIBERS

The commercial fibers of the monocotyledons are strands of elongated, more or less lignified sclerenchyma cells associated with vascular tissues. Those used in cordage, coarse textiles, etc., come mostly from huge leaves or leaf-bases. The principal members of the group are abacá or manila, henequen, sisal, and New Zealand flax.

Abacá or Manila

This strong and valuable fiber is from the sheathing leaf-bases of *Musa textilis* (Fig. 170), a bananalike plant of the Philippines. This is both wild and cultivated in mountainous regions; the better grades of fiber are from cultivated plants. The large central structure which appears like a stem is formed, like that of the banana, from concentric leaf-bases. These "stems" rise in clumps from a rhizomatous base. The fruit is bananalike but large-seeded and inedible.

Propagation is from seeds, suckers, or rhizome-cuttings; the latter are preferred. The first abacá crop matures in thirty to thirty-six months; cutting can be repeated after three to four years.

The sclerenchymatic strands of abacá form a rind beneath the epidermis; they are readily stripped off in ribbons. Fibers are cleaned from associated tissues by drawing the ribbons under a rude knife pressed by a spring against a hardwood block or rod. Fiber-strands are six to twelve feet in length and very uniform. A man can clean some fifty pounds per day. Well-cleaned manila (Fig. 171) is buff-white and lustrous; when less carefully processed, the fiber reddens in drying. Dried abacá is shipped in bales of about 270 pounds.

Manila (Fig. 172) is a coarse and extremely strong fiber, even stronger than hemp, which it has largely replaced in cordage. It is mostly employed in cables and ropes; about half of those made in the United States are of abacá. It is resistant to water,

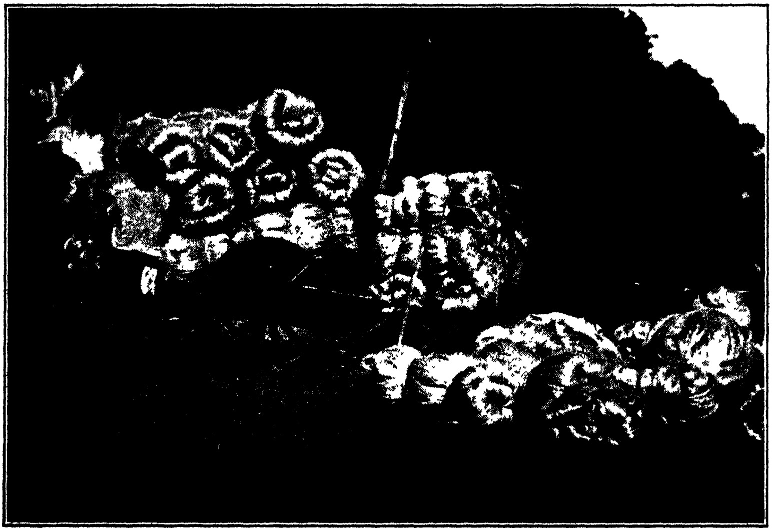

FIG. 171. — Abacá Fiber in Bundles as It Is Taken from the Plantation to the Market in Davao, Philippine Islands. (Courtesy Bureau of Plant Industry.)

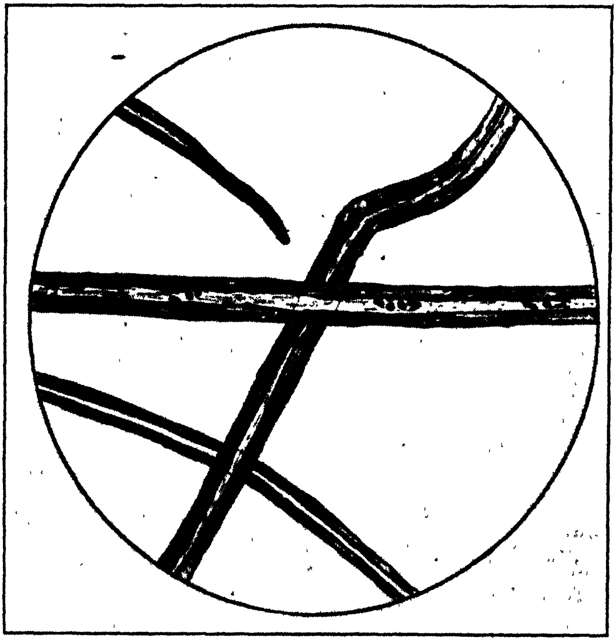

FIG. 172. — Abacá Fiber. (Reprinted by permission, from *Textile Fibers*, by the late J. Merritt Matthews, published by John Wiley & Sons, Inc.)

swells little when wet, and is therefore valued for hawsers (Fig. 173), ships' cables, and riggings. It makes the best and most flexible well-drilling and hoisting-cables. The best grades of binder twine are made of manila.

The relative strengths of abacá and hemp ropes are about in the ratio 12: 10.

Fine strands of manila are spun into thread and used in coarse weaving and upholstering. In the Philippines, rather fine fabrics are made of it. Tagal hat braid, much used in women's hats, is fabricated in Japan from Philippine abacá.

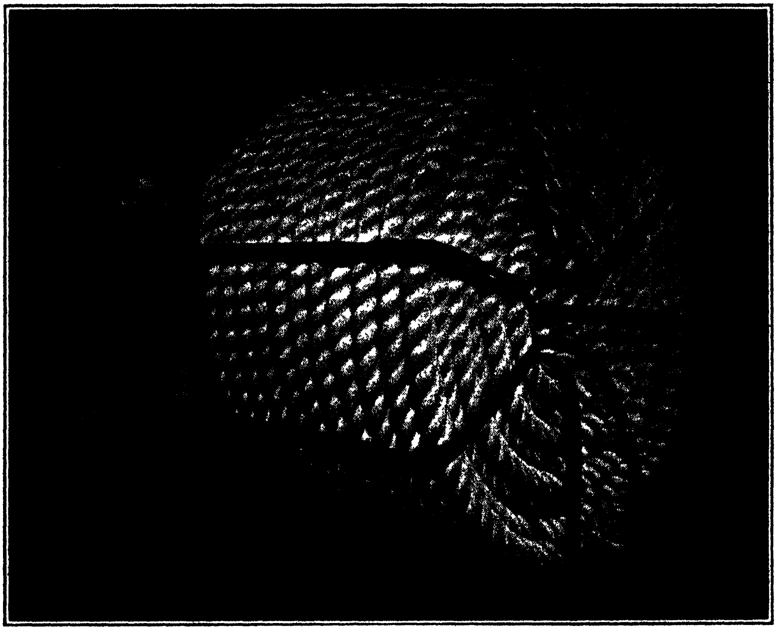

Fig. 173. — A Large Manila Hawser. (Courtesy of Tubbs Cordage Company.)

Old manila rope and manila wastes are used in manila paper, a very tough product.

American imports of manila for 1923 were about 106,000 tons. Following years showed considerable decrease.

Henequen and Sisal

These fibers are from leaves of closely related tropical plants, *Agave fourcroydes* and *A. sisalana.* These are close relatives of the "Century Plant" commonly grown in the warmer regions of the United States and elsewhere as a tub or conservatory subject.

Henequen and sisal are both natives of Yucatan; but sisal is now grown in widely scattered tropical regions, while henequen production is still largely limited to Yucatan, with some production elsewhere in Mexico and in Cuba. Henequen and sisal plants and products are considerably confused in common usage and in the market.

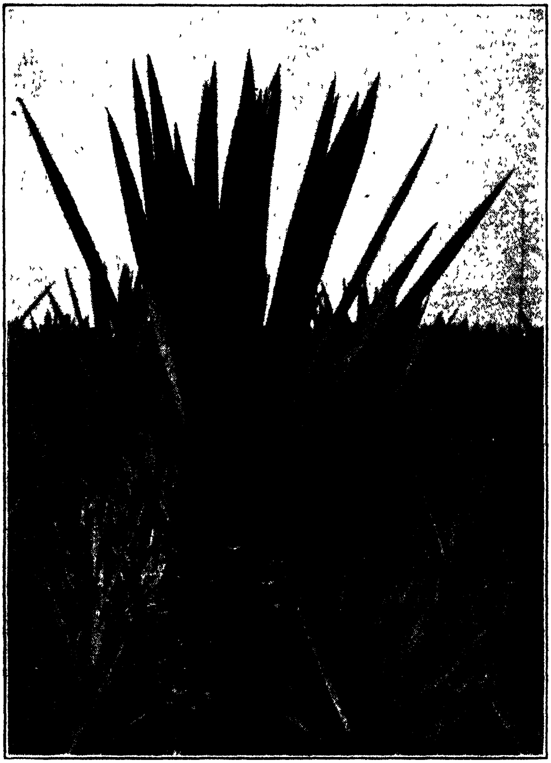

FIG. 174. — Henequen (*Agave fourcroydes*). (Courtesy of Bureau of Plant Industry.)

The henequen plant (Fig. 174) has a massive stumpy caudex, which reaches six feet in height. It attains an age of ten to twenty years or occasionally more. The leaves grow in a thick rosette at the top; the lower ones are harvested. Their blades, fringed with hooked spines and with a sharp needlelike termination, are thirty to sixty inches long, four to five inches wide. Flowering plants throw up a single stalk fifteen to thirty feet high; this produces a huge branching cluster of yellow flowers from which develop either seed-pods or bulbils. Death follows flowering; some plants die without blooming. Suckers, which form at the base of the plant, are chiefly used for propagation.

Henequen is grown in full sunlight in well-drained, more or less arid soil which is often too rocky to be plowed. The plant is a typical xerophyte. In rich soil and with abundant moisture it produces pulpy leaves with little fiber. Leaf-cropping begins at the sixth or seventh year, after which harvest is made semi-annually for ten to fifteen years or as long as good leaves appear.

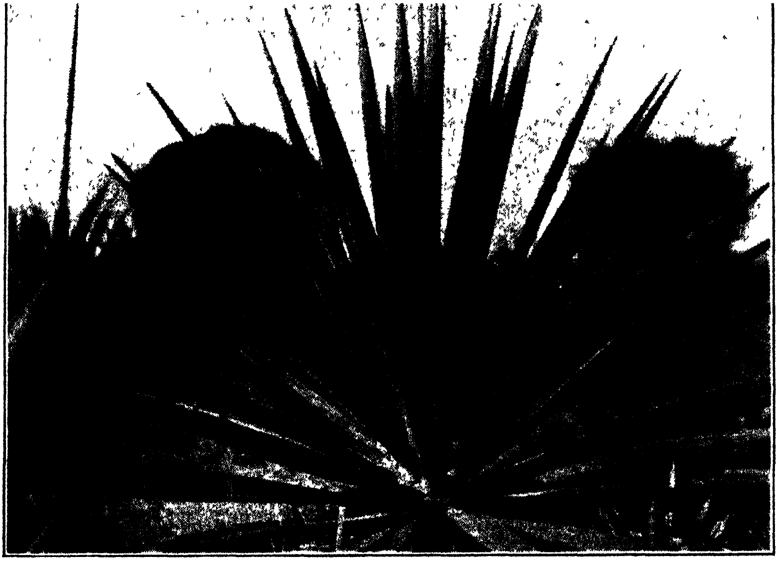

FIG. 175. — A Sisal Plant (*Agave sisalana*), Four and One-Half Years Old, with Ninety-Seven Leaves Forty to Fifty Inches Long. (Courtesy Bureau of Plant Industry.)

Leaves are cut; spines and tips are removed and the leaves are bundled by hand. They are then cleaned in any of several types of machines, all of which beat, scrape, and wash the product until only the long, clean fiber remains. This is dried in the sun or sometimes in centrifugal machines.

This machine cleaning, which is also employed with sisal, affords these fibers a price-advantage over manila, for which fiber no machine-process has yet been devised. Fiber-yield is 3–4 per cent of the leaves' weight.

The sisal plant (Fig. 175) is of very similar character. It is of more rapid growth, shorter lived, and seems to be more adaptable to climatic and soil variations. Both sisal and henequen were brought into Florida nearly a century ago. Henequen failed to thrive, while sisal soon became naturalized. Exportation of propagating stock from Mexico is prohibited; it is said that the sisal plantations of Africa, Sumatra, Java, India, and Haiti may all be traced to bulbils from Florida.

Sisal leaves may be harvested eighteen to thirty-six months after the setting of bulbils or suckers, after which semi-annual cuttings may be made for four to six years.

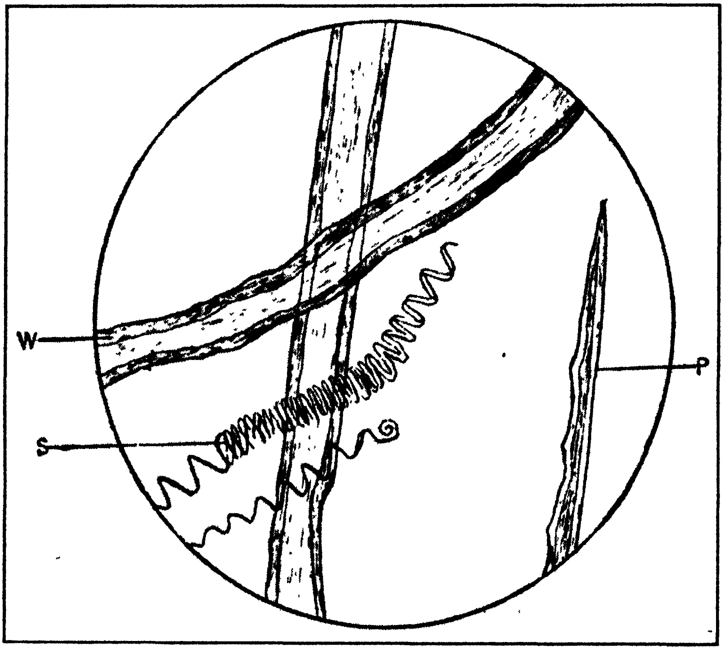

FIG. 176. — Sisal Fiber. *W*, cell wall; *S*, spiral thickening; *P*, end of fiber. (Reprinted by permission, from *Textile Fibers*, by the late J. Merritt Matthews, published by John Wiley & Sons, Inc.)

Sisal and henequen, when properly prepared, are among the whitest of fibers (Fig. 176). They are harsher than manila, less strong, and more inclined to swell when wet. Either or both are often mixed with other fibers. Henequen is the chief source of binder-twine and small ropes. Sisal is preferred for making lariats. The use of the combine, which threshes without binding, has considerably decreased the demand for binder twine.

In recent years between 100,000 and 136,000 tons of these fibers have been imported. About 90 per cent of this amount has usually been henequen. Production of sisal is increasing, and this fiber is coming to be more important as a competitor of henequen.

Large leaves of several other Agaves and related monocotyledons also yield commercial fibers. Of these the coarse strands of Mexican istle, or Tampico, are substituted for animal bristles in brushes; they are also used for lath twine and other cheap cordage.

New Zealand Flax

This fiber is from the long, swordlike leaves of *Phormium tenax,* of the Liliaceæ. As the common name is botanically misleading, phormium has been proposed as a fiber name, but it has not gained common usage.

New Zealand flax is cultivated in Australasia and is sometimes seen as an ornamental in America. The leaves are five to eight feet long and six to eight inches wide; they may contain as much as 20 per cent of fiber. The product is elastic but rather soft for a leaf fiber and very tough. It is chiefly employed in binder twine, baling rope, and cordage; often in mixture with sisal, henequen, or manila.

American annual imports of New Zealand flax range between 3,000 and 5,000 tons.

5. Other Fibrous Products

Coir, Raffia, Spanish Moss, and Kapok

Several other fibers, of most varied character, may be very briefly mentioned. Coir, the rough brownish material of coconut husks, is chiefly from British India and Ceylon. Coir is light, tough, very resistant to mechanical wear and to wetting. It is used for coarse matting, doormats, cordage, and upholstery stuffing. Coarse coir is made into brushes.

Raffia, a product once in great vogue for hand-plaiting, is fibrous strips of the leaf-epidermis of the African Raffia Palm, *Raphia Ruffia.* These leaves attain a length of twenty-five feet.

Tillandsia or Spanish moss is the entire gray-fibrous plant of an epiphyte, *Tillandsia usneoides,* mainly employed as upholstery stuffing. It is collected in Florida and the Gulf States.

A downy product used in mattresses and pillows is kapok, from the inside of the pods of several species of trees of the Bombacaceæ. The trees are known as silk-cotton trees. From 7,000 to 10,000 tons of kapok are imported annually, chiefly from Java.

CHAPTER VIII

PAPER AND PULP

1. PAPER AND OTHER MATERIALS OF RECORD

The Nature of Paper

Paper is an artificial tissue of pressed felted fibers. The fibers are almost invariably of vegetable origin. As a universal medium for record and for transmission of thought and experience, paper is one of the foundation materials of modern civilization. Civilization, in fact, has grown up about the possibilities of ready record afforded by the alphabet and by paper. As a wrapping and packing material, as an ornamental product, and in numerous capacities beyond present possibility of cataloguing, paper touches our everyday life in myriad ways, some prosaic enough, but extremely essential.

The beginnings of the paper industry are lost in antiquity. Long before the dawning intellect of man felt any need of record, paper-wasps had demonstrated the utility of pulped wood as building material (Fig. 177). Man apparently was slow to grasp the possibilities of paper. The earliest records which have come down to us are engraved upon bone or stone, or pressed into brick. Primitive peoples also used the skins of animals; first, probably, as a medium for crude draughting and painting, and later for record purposes.

Papyrus

Among the earliest of vegetable writing materials was papyrus or byblus, a product of the stems of *Cyperus Papyrus* (Fig. 178) and other large, rushlike *Cyperus* species of the Levantine region. From a cultural standpoint, papyrus rolls are among the most valuable trophies of archeological research in Egypt. Some of them apparently antedate the Christian era by 2,500 years; among them have been found records of a culture a thousand years older than that. Papyrus was also used by the Assyrians, the early Greeks, the Romans, and probably by others of the Mediterranean, Asiatic, and North African peoples.

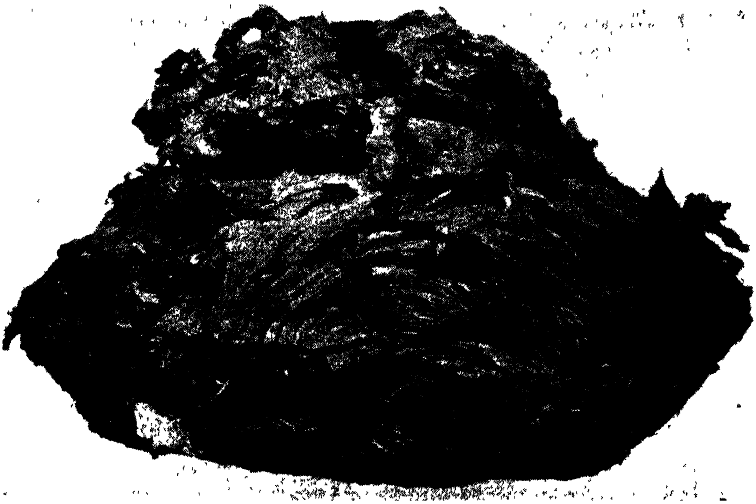

FIG. 177. — Architecture in Paper. The home of a paper wasp. (Courtesy of Bureau of Entomology.)

FIG. 178. — The Tassel-like Growth of *Cyperus Papyrus* in a Swamp in Africa. Lotus in the foreground. (Photo from American Museum of Natural History.)

Ancient papyrus manufacture seems to have been largely an Egyptian industry. The exact method used is somewhat uncertain. The inner regions of the culms of papyrus (Fig. 179) consists of a parenchymatic fundamental tissue traversed by small but tough fibro-vascular bundles. The stems seem to have been cut into longitudinal strips which were laid side by side and covered with another layer at right angles, or possibly interwoven. This lattice-fabric was thoroughly soaked, beaten, perhaps with the addition of paste, into a coherent sheet, and then dried in the sun. Sheets were pasted together into rolls of considerable length. Both in the excellency of their preservation and in the permanency of their ink, ancient papyrus documents (Fig. 180) have set records which will be difficult for modern paper to equal.

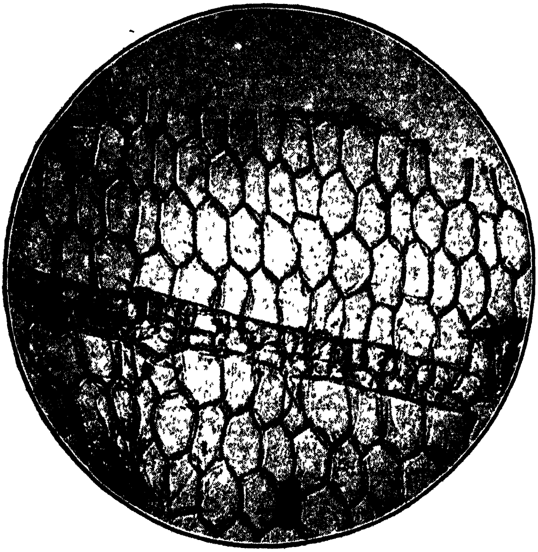

FIG. 179. — Papyrus, photomicrograph. (Reprinted by permission, from *Textile Fibers*, by the late J. Merritt Matthews, published by John Wiley & Sons, Inc.)

Early Paper-Making

Egyptian cultivation and manufacture of papyrus continued until the tenth century A.D., after which period the use of this ancient material was replaced by that of paper. The latter had come into the Mediterranean region about two centuries before.

Paper-making, like many other fundamental contributions to civilization, seems to have originated in China. Just when the discovery occurred is quite uncertain. Paper, unless very carefully preserved, is a most perishable material, and no doubt the sheets of its earliest record have long since mouldered away.

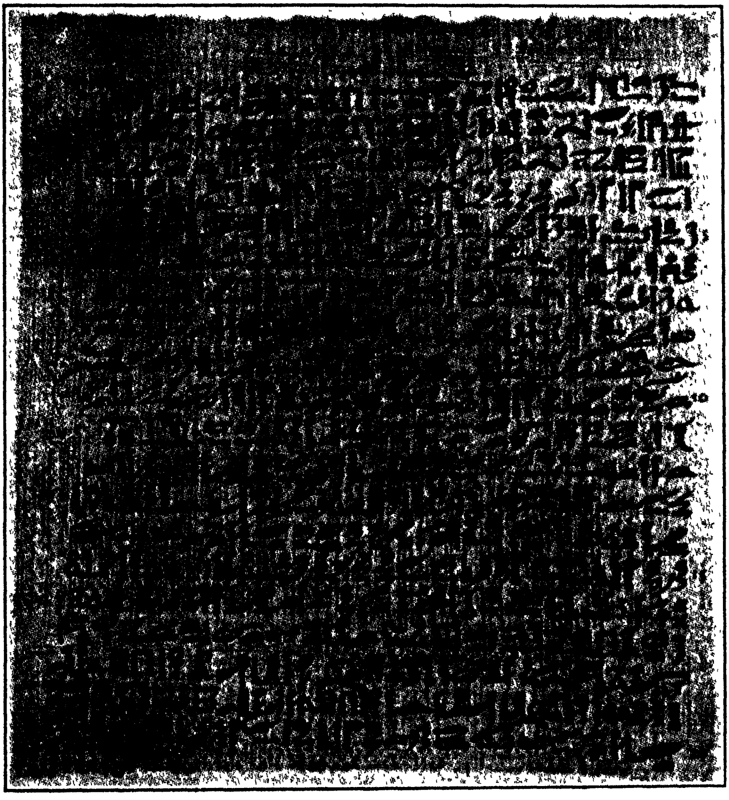

FIG. 180. — The Papyrus Ebers, an Ancient Egyptian Document Relating to the Early Practice of Medicine. (From C. P. Bryan, *The Papyrus Ebers*, D. Appleton and Company, n. d.)

Explorations of ruins of the Great Chinese Wall in Turkestan have discovered papers, now preserved in the British Museum, which were made at least as early as 150 A.D. The introduction of paper to the Western world is said to have resulted from warfare between Chinese and Arabs in about the eighth century, in which a number of Chinese paper-makers were taken and set to work by their captors. Arabian culture, at that time in its zenith, seized eagerly on the new material. Many Arabian manuscripts of the ninth century, still exist, written on paper probably made from flax. From Arabia, paper-making spread into Greece, to Sicily, at that time an Arabian province, and to Moorish dominions in Spain.

Parchment and vellum were the principal writing surfaces of early and medieval Europe. These were made from sheepskin and calfskin; they afforded permanency, flexibility, and an excellent writing surface. In a day when education was confined to the few and when printing was unknown, parchment and vellum were cheap enough and abundant enough for the scant demands of culture and record; they maintained themselves against the inroads of paper until the thirteenth and fourteenth centuries. European records written on Oriental paper in the twelfth century are still in existence. Paper-making in Italy, France, Germany, and probably England was well established before 1400. Not long after that date the introduction of the printing press marked the beginning of that marvelous development of the art of letters which entitles our present era to the name of the Age of Paper.

2. PAPER-MAKING MATERIALS

The fibrous substances which form ordinary paper include the cellulose material of elongated plant cells, in varying degrees of purity. The paper of the Chinese Wall, mentioned above, seems to be of rag stock, and early paper was made mostly of linen or more rarely cotton rags. Both of these represent cellulose fibers in a high degree of purity. The relatively high price and limited supply of rags has brought about the use of many fibrous vegetable substances, of which wood pulp is chief. The process of paper-making consists essentially in isolating and in various degrees purifying and bleaching the fibers, floating them in water, felting them in a sheet upon a screen, pressing out the excess water with more or less concurrent addition of various "fillers" designed to add weight and luster and to prevent ink from spreading.

Wood Pulp

It has been previously shown that wood consists largely of elongated fibrous cells whose walls are mainly of cellulose and lignin. The woods of the gymnosperms (Fig. 181), in particular, are of highly homogeneous character, consisting in the main of tracheids which are comparatively long and tough, easily torn apart, and rather readily freed from lignin and other non-cellulose matters. Woods of gymnosperms which are of light color, straight grained, and relatively low in resin, are preferred for pulping. Various species of Spruce (*Picea*) and Fir (*Abies*) are the chief sources of wood pulp; other conifers and the softer hardwoods are being used in increasing quantity.

Pulping Methods

Wood may be reduced to pulp by MECHANICAL or by CHEMICAL means. Most papers and paper boards represent blends of different kinds or grades of pulped material. The structure of bark differs from that of wood; it is generally deeply colored, contains little valuable fiber and much tannin. Therefore it is usually removed before any pulping process is undertaken, as are also the hard and resinous knots.

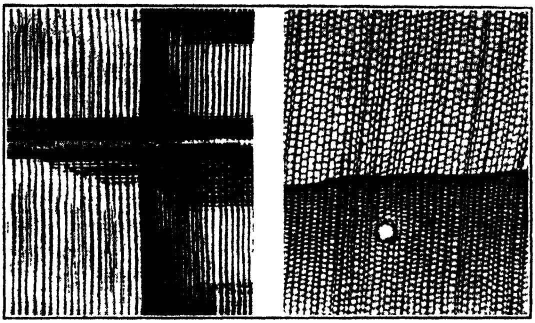

FIG. 181.—The Wood of White Spruce (*Picea glauca*), in Radial- and Cross-Section. This is a species commonly used for pulping. (Photomicrographs from United States Forest Products Laboratory.)

GROUND WOOD PULP

Mechanical pulp or ground wood is made by grinding the peeled wood upon grindstones (Fig. 182). The friction of the process generates considerable heat. This can be controlled to any desired degree by the use of water, which also prevents too great tissue-destruction in grinding. "Freeness" of the pulp—the quality of draining rapidly on the paper machine—is promoted by a certain degree of heat in grinding; American mills produce chiefly a hot-ground pulp at a temperature of about 150° F. The use of larger quantities of water, as in European mills, affords a cold-ground product which is finer and more even. After grinding, the pulp is washed, drained, pressed, and rolled into sheets of convenient thickness. Some pulp mills manufacture paper, but frequently the pulp is sold in laps—folded, blanketlike forms—to paper mills, in whose manufacturing processes it is blended with other types of pulps.

This grinding process, it will be seen, makes little or no change in the chemical characteristics of the wood. At best, the fibers are much abraded and broken (Fig. 183); economy dictates the use of long-fibered woods of even texture, whose cells are readily parted by abrasion. Only the lightest colored woods, such as spruce, can be used for the ordinary purposes of ground wood without expensive bleaching. Spruce is the mechanical pulpwood *par excellence;* nearly 90 per cent of the ground wood pulp of the United States and probably fully as large a proportion of the Canadian output is made of spruce. Firs and hemlocks furnish nearly all the rest. Besides other disadvantages, the dense structure of most hardwoods necessitates from two to

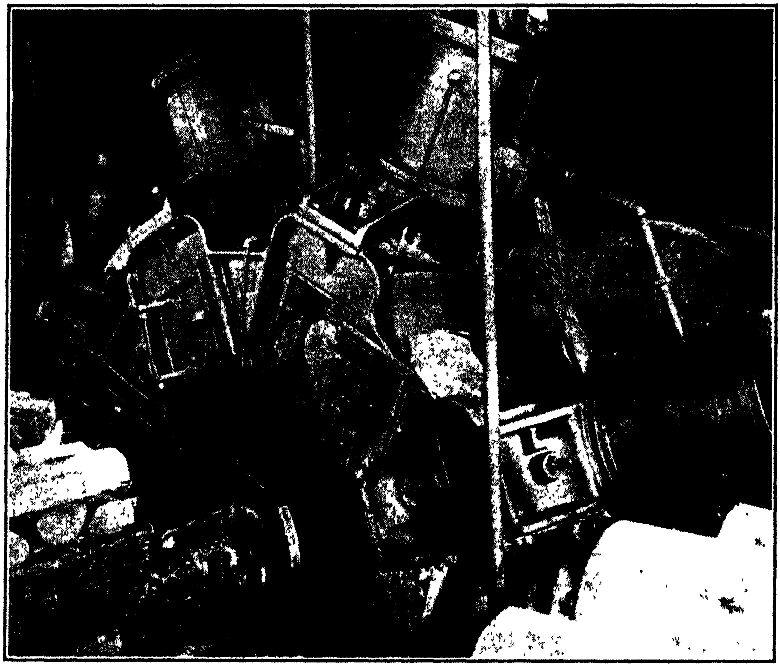

FIG. 182. — A Four-Pocket Wood-Grinder. Billets of wood are placed inside the pockets, two of which are shown open. When the pockets are closed, hydraulic pressure of about seventy pounds per square inch is applied; this holds the billets against the rapidly revolving grindstone within the housing below the pockets. One of these grinders will reduce about six to nine cords of wood in twenty-four hours. (Photo from United States Forest Products Laboratory.)

three times as much power in grinding, and the process is ruinous to their fiber.

Mechanical pulp is used very largely in the making of newsprint paper. As the fibers are irregularly broken, still lignified, more or less resinous, and comparatively stiff, the addition of some sulphite pulp—20 to 30 per cent—is necessary to prevent breaking and tearing of the paper in use.

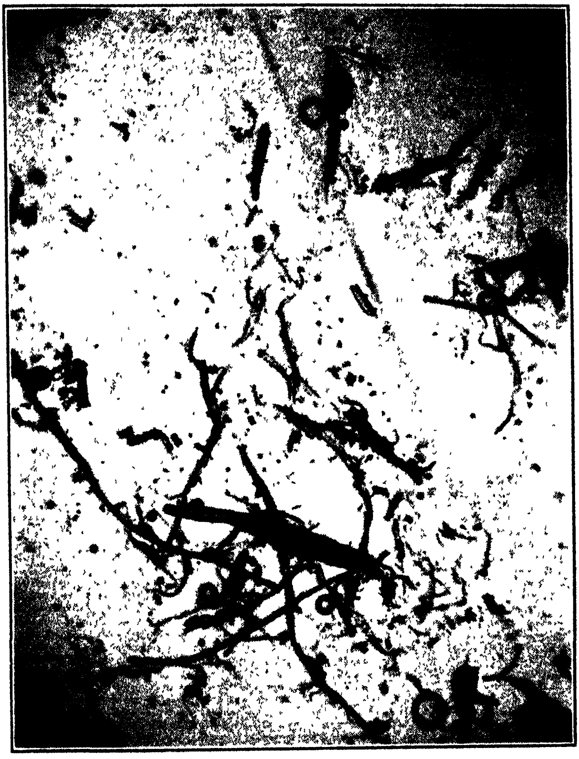

FIG. 183. — A Mechanical Pulp from *Picea glauca*. (Photomicrograph from United States Forest Products Laboratory.)

CHEMICAL PULPS

In the manufacturing of these products various reagents are used which dissolve the material of the intercellular layer and the lignin of the cell wall and leave a fibrous residue of nearly pure cellulose. Three standard procedures—known as the SULPHITE, SODA, and SULPHATE processes—afford practically all chemical pulps. In any process, the wood is usually barked and must be chipped and crushed before cooking. Chemical pulp to be used for high-grade paper usually undergoes a further bleaching process.

From the standpoint of output and values the SULPHITE PROCESS is the most important of pulp-making procedures. The chipped wood is cooked or digested with sulphur dioxide in solution with calcium or magnesium bisulphite, or both, in steam under pressure at high temperature. Lignin is dissolved, but not bark, which therefore must be carefully removed before the wood is cooked. Pitch, tannins, and some other extractives are scarcely affected; decayed wood pulps poorly. The sulphite process is largely limited to spruces, firs, and hemlocks; it appears suitable, also, to some of the hardwoods such as birches and maples. Long fiber is essential; color is less important, although of course whiteness or readiness of bleaching are advantages. Details of cooking vary widely according to the kind of wood and the character of pulp desired. Sulphite pulp is the great general-purpose paper material; as previously stated, it is an essential ingredient of newsprint. It is often the chief, and sometimes the sole, component of some

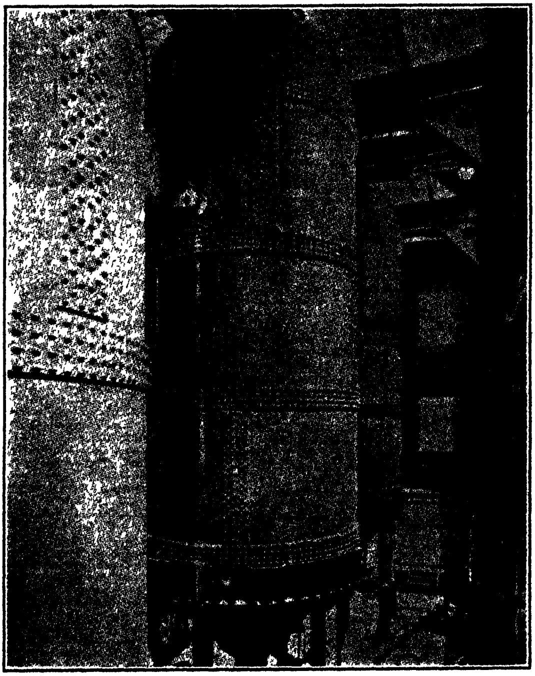

FIG. 184. — Digesters in a Sulphite Mill. (Photo from United States Forest Products Laboratory.)

grades of book and magazine paper. It is blended in a wide variety of other papers, paper boards, and other pulp products.

The active agent in the digestion of SODA PULP is an aqueous solution of sodium hydroxide. This reagent dissolves bark, knots, pitch, and decayed wood as well as sound wood; stock is usually peeled, however, as the bark consumes alkali and yields no pulp. The soda process was introduced to handle aspen, other poplars, and similar non-coniferous woods; it is being increasingly employed for the more resistant hardwoods. Soda is little used for conifers because soda pulp from these bleaches poorly. As hardwoods come into increasing use in paper manufacture, the soda process seems destined to become still more important. Soda pulp is largely used bleached, in book, magazine, lithograph, and other printing papers. Unsized soda pulp is the chief source of blotting paper.

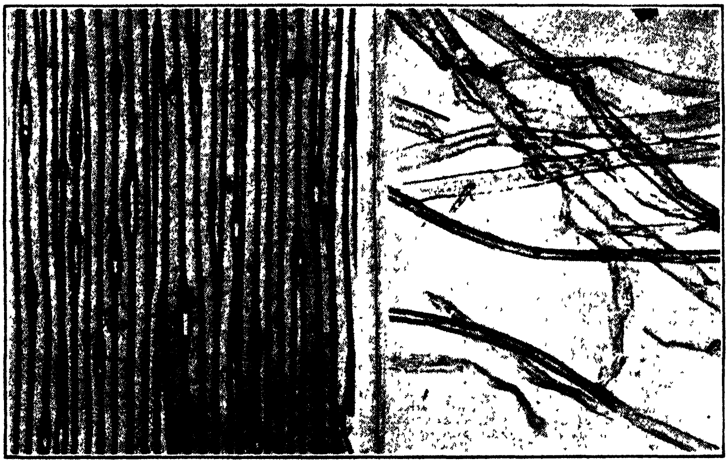

FIG. 185. — Western Yellow Pine (*Pinus ponderosa*) in Tangential Section and a Sulphate Pulp Made from It. (Photomicrographs from United States Forest Products Laboratory.)

The SULPHATE PROCESS is generally employed for coniferous woods but may be used for others. Sulphate pulp is made by a recent modification of the soda process in which sodium sulphide is added to the alkaline liquor. The process often yields a higher percentage of pulp than the sulphite or soda processes. The product is extremely strong and is chiefly used with little or no bleaching in making kraft wrapping paper, paper bags, and container board. When bleached, sulphate pulp yields an excellent grade of printing stock. The main drawback to the sulphate process consists in development of odors so disagreeable as to render a sulphate plant decidedly obnoxious in a community.

The Principal Woods Used in Pulping

These are shown in the following table:

TABLE V

PULPWOOD CONSUMPTION—QUANTITY, BY KIND OF WOOD AND PROCESS OF MANUFACTURE, FOR THE UNITED STATES: 1930 *

KIND OF WOOD	PROCESS OF MANUFACTURE (CORDS)					
	Total	*Mechanical*	*Sulphite*	*Soda*	*Sulphate*	*Semi-chemical*
Total.....	[1]7,195,524	1,467,683	3,135,093	850,229	1,692,933	49,586
Spruce:						
Domestic ..	1,844,937	854,526	937,530	3,582	49,299	....
Imported ..	888,255	298,061	568,199	19,028	2,967	.....
Hemlock......	[2]1,222,961	146,154	843,599	1,357	231,851	.....
Yellow pine, southern....	1,030,273	9,892	32,103	79,957	908,321	......
Poplar:						
Domestic ...	291,897	32,704	14,415	244,403	375	......
Imported ...	159,092	965	300	157,827	....	.....
Balsam fir:						
Domestic....	330,548	61,067	210,899	3,754	54,828	.....
Imported ...	48,935	6,090	39,845	....	3,000	.....
Jack pine......	200,970	12,371	....	....	188,599	......
Chestnut......	156,299	....	39,839	69,724	....	46,736
Yellow poplar..	107,795	610	.. ..	107,185	....	.....
White fir......	90,652	25,484	63,685	....	1,483	......
Beech, birch, and maple...	68,848	....	11,531	57,317	....	......
Gum..........	41,825	500	....	38,475	....	2,850
Tamarack (larch)......	40,054	....	979	....	39,075	......
Other woods [3]..	76,681	3,977	211	49,592	22,901	......
Slabs and mill waste.......	[1] 595,502	15,282	371,958	18,028	190,234	......

* From Bureau of Census, Forest Products: 1930.

[1] Includes data for a small quantity of spent licorice root of no market value.

[2] Includes data for a small quantity of imported hemlock.

[3] Domestic cottonwood, Douglas fir, white pine, and willow, and domestic and imported basswood.

The spruces (Fig. 186) form the principal pulpwood group. The fibers (*tracheids*) pulp readily, yielding an excellent product

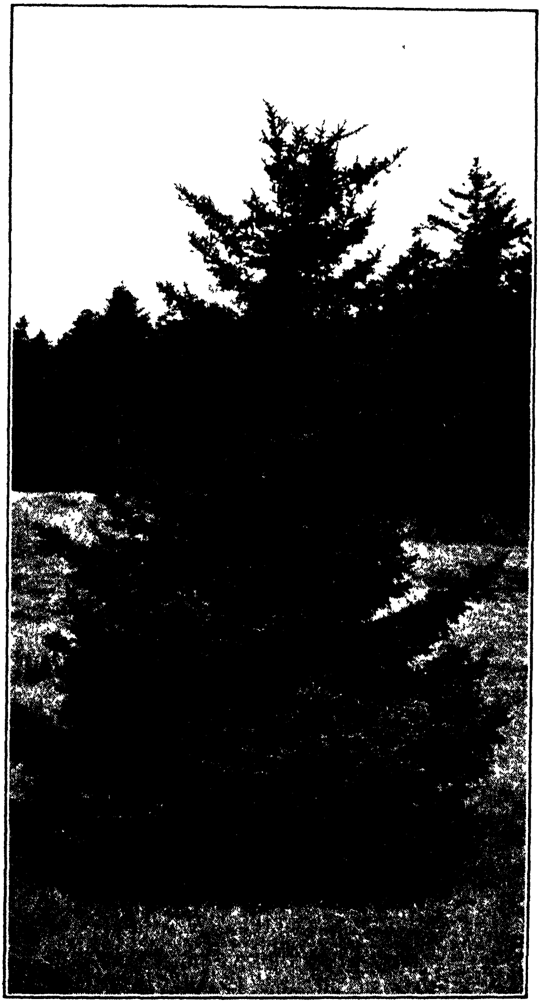

FIG. 186. — A Small Specimen of Red Spruce (*Picea rubra*). This is the principal pulp-spruce of the United States. (Photo from United States Forest Service.)

by any process. Given spruce in abundant supply, there would be little demand for other pulp woods save for the highest grades of book paper and other specialties. Owing, however, to the constant depletion of the spruces and their rather slow natural replacement, wide interest has been evoked in other woods and other cheap, or waste, plant material as paper sources. To this end, extensive investigations have been made by the United States government and by various paper manufacturing interests.

Of hemlocks, which in the United States rank second for pulpwood, the Western species, *Tsuga heterophylla,* resembles spruce in its characters, but is less easily ground. *T. canadensis,* the Eastern Hemlock, is less desirable; its pulp is inferior in strength and color and requires more bleach. In early American forest exploitation hemlock was considered almost worthless for any purpose save tan-bark; millions of feet were peeled and left in the woods to rot. Hemlocks are among the slow-growing conifers, and the available Eastern supply is not large.

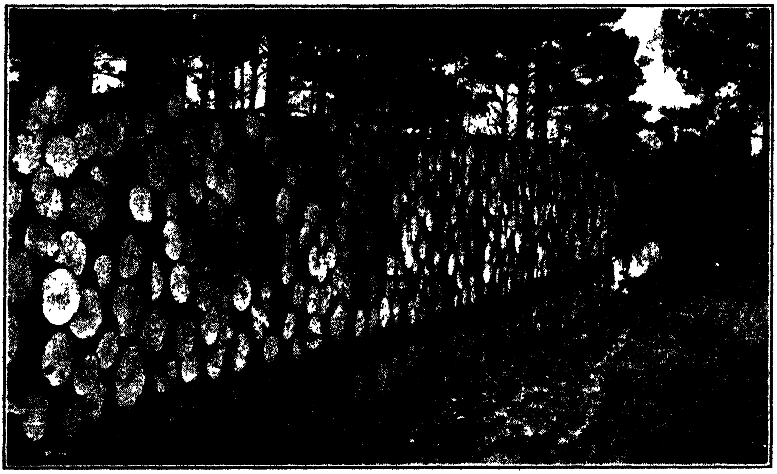

FIG. 187. — Pulpwood from the Loblolly Pine (*Pinus Taeda*). Demand for pine pulpwood in the Southern States is growing with the development of the sulphate process. (Photo from United States Forest Service.)

The firs (*Abies* spp.) are close to the spruces in pulping quality. The largest stands in the United States are in alpine regions of the Rockies and the Sierras, distant from the present regions of pulp-making. Pines vary greatly in their pulping characters. Their resin or pitch content usually interferes with grinding and with the success of the sulphite process. Practically all the pines (Fig. 187) in commercial pulp use are reduced by one of the alkaline methods, chiefly the sulphate process. Other conifers are for various reasons inferior pulp sources. Few are at all suitable for grinding. Some, such as redwood and red cedar, have objectionable color; these and also the white cedars are too light in weight for economical use.

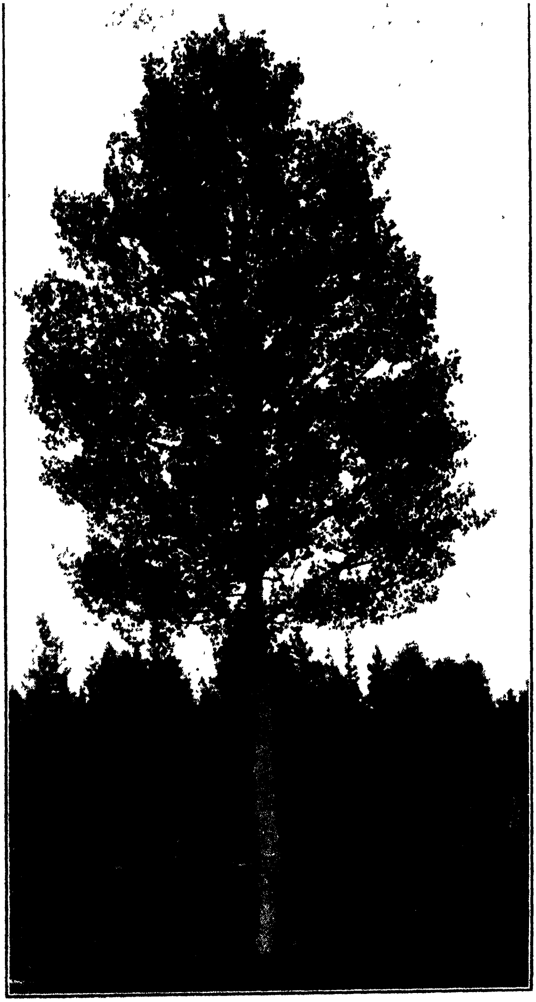

Fig. 188. — An Aspen (*Populus tremuloides*). This species is the principal angiosperm used for pulping in the United States. (Photo from United States Forest Service.)

Hardwoods, in general, are rapid-growing and tend to replace conifers in cut over or burned areas, particularly in the East. Aspen (Fig. 188), especially, takes over burned lands in the

Northern States and Canada. Paper manufacturers are reported to keep careful record of fire-areas in expectation of harvesting, in later years, this wood which is so highly valued for soda pulp. The softer hardwoods, such as the poplars and lindens, handle readily by the soda process; some can be handled by the sulphite method. In recent years, the Forest Products Laboratory of the United States Department of Agriculture has been actively investigating pulping properties of little used species, and it appears likely that the use of hardwoods will increase, particularly as the spruce disappears. Ailanthus, an Asiatic tree rather commonly introduced in the United States, has been suggested as a possible pulpwood crop. Results of promise have been attained in the hybridizing of poplars; these trees, always rapidly growing under favorable conditions, afford strains of remarkable "hybrid vigor" (Figs. 189, 190). Commercial culture of pulpwood seems bound to come.

WOOD WASTE

It has been previously noted (Chapter IV) that large quantities of wood are wasted in ordinary lumbering operations. Some progress has been made in pulping of slabs, butt cuts, and other rather large pieces of waste. Among the obstacles is the irregular shape of most wood refuse which renders difficult both the removal of the bark (the major bulk of the slabs forming the principal waste of lumber in sawing) and the chipping or grinding operations. Some Southern mills pulp yellow pine waste by the sulphate process, in which the presence of some bark is not a serious detriment. Wood waste is also used in making products of coarse texture, such as fiber-board and insulation boards. New handling and pulping processes are being devised for waste wood, and the use of this for paper will probably increase.

Crop Wastes as Pulp Sources

Products of practically all woody and herbaceous plants can be pulped more or less readily. The utilization of any such material hinges upon price, which must be extremely low; upon large and constant supply; upon expenses of handling and processing; as well as upon yield and quality of pulp.

Among the greatest of crop wastes or by-products are cotton stalks, cereal straws, corn stalks, flax straw, and the wastes from sugar and molasses manufacture. Cotton stalks alone are pro-

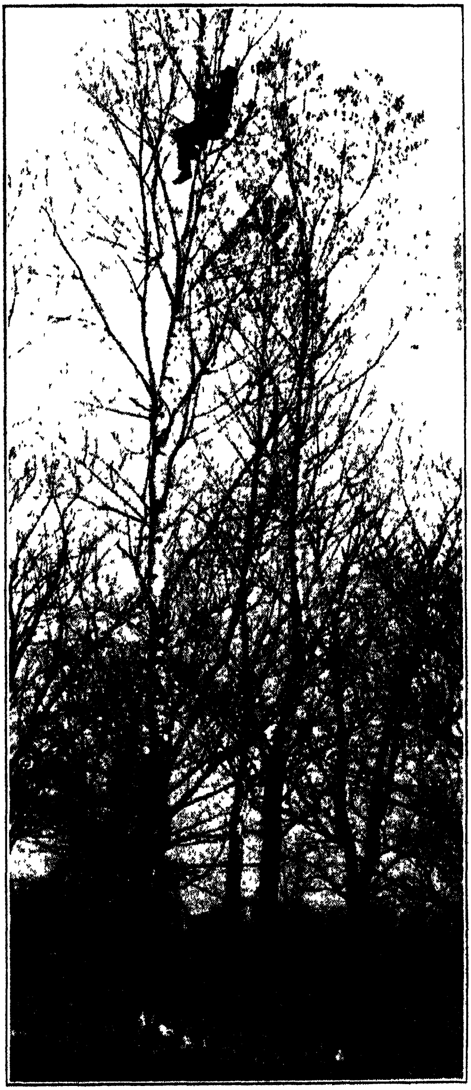

FIG. 189. — Obtaining Seed for Breeding of Poplars. This work is usually done high up in the trees, which must be climbed (1) to enclose female flowers before they are ready for pollination, (2) to secure pollen, (3) to make the pollination, (4) to remove paper bags when the pistils are no longer receptive, (5) to enclose maturing capsules in order to prevent loss of seed, and (6) to collect the ripe seeds. (From Stout, McKee, and Schreiner in *Journal of New York Botanical Garden.*)

duced at the rate of 10,000,000 tons per year. Too woody for feeding, too small and too much branched for economical fuel use, they are among the most wholly valueless of vegetable substances. All through the Cotton Belt, they can be had in quantity for the cost of haulage. So far, however, cotton stalks afford little promise as a paper source; they can be pulped only by expensive and difficult processes, and the resulting product is of

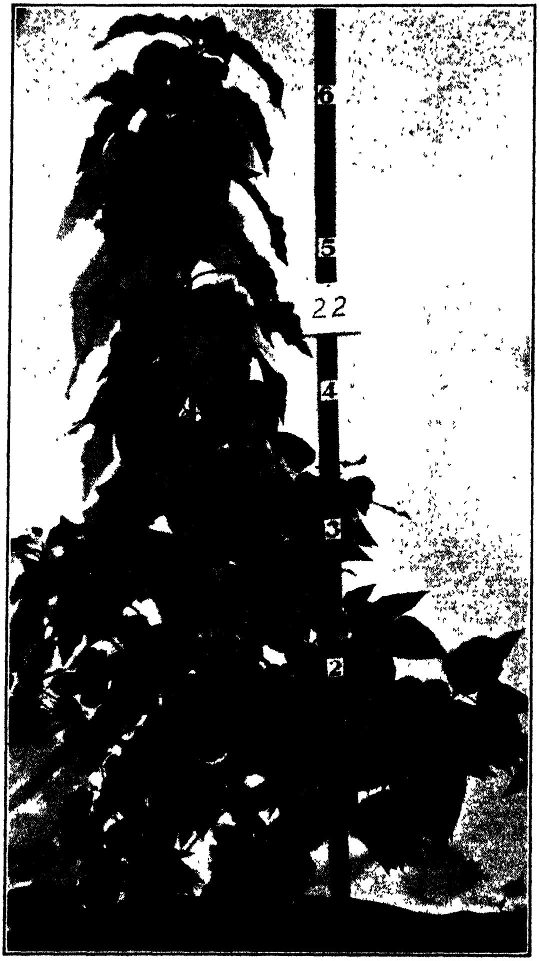

FIG. 190. — A Hybrid Poplar, *Populus balsamifera virginiana* X *P. trichocarpa*, at the End of the Second Summer of Growth from Seed. (From Stout, McKee, and Schreiner in *Journal of the New York Botanical Garden*.)

poor quality. Corn stalks are a crop waste over an even wider area, and their annual production is probably even greater than that of cotton stalks. Their bulk consists largely of short-celled parenchyma, with little fiber; ordinary pulping processes afford a gelatinous mass which makes a hard, brittle, and weak paper. Investigations by the Forest Products Laboratory are reported to have developed a modification of the soda process by which an excellent grade of corn stalk pulp is made, suitable for blending with wood pulp in paper manufacture.

Cereal straws are quite extensively used in pulping, chiefly for the manufacture of the heavy board known as strawboard, used for packing boxes, in which bleaching is not essential. Among sorghum products is broom corn, of which only a small portion of the plant is used in making brooms; the rest is capable of yielding excellent pulp, but present farm practices of harvesting militate against its use. Of sugar by-products, the utilization of cane bagasse for heavy insulation board is practised to some extent, but in the United States this is a seasonal product and ill adapted to preservation for an all-year pulping industry.

Textile Wastes

Cotton and linen rags—consisting as they do of long, strong, and practically pure cellulose fiber—were in the early years of the paper industry a principal source of supply. At present, linen and cotton rags and also the short fuzz of upland cotton known as linters are in demand for the manufacture of the highest grades of book paper, for India paper—an especially thin but tough and opaque product used in Bibles and for high-priced books where economy of bulk is desired—and for other papers characterized by extreme permanence and whiteness. However, a "linen finish" is easily imparted to wood-pulp products containing no rag whatever. Little textile flax is now grown in North America, but considerable quantities of flax fiber wastes are imported for papermaking. This stock is largely used in counterboard for shoes, and in the extremely tough, elastic cardboard of shotgun cartridges.

About 1,500,000 tons of flax straw accumulate annually as a waste of the flax-seed raising industry, but efforts to utilize this have not so far met with commercial success. Domestic supplies of flax tow are too expensive or of too low quality to compete with imported flax wastes.

Old rope and rope wastes of hemp and manila yield especially tough paper. Hemp flyings, a by-product of rope-making, are well adapted for use in India paper. Hemp hurds, a coarse waste fibrous material resulting from the preparation of hemp fiber, are also used. Old burlap and jute wastes are employed in paper board.

Grasses as Pulp Sources

The ordinary small grasses are of little promise in paper-making. A few large species are somewhat used. Esparto (*Stipa tenacissima*) and another Mediterranean grass, *Lygeum Spartum*, are employed in Europe, and the papers are occasionally imported for special purposes, such as book-making. Zacaton (*Epicampes macaroura*) is a huge Mexican grass whose roots are used in brush-making; on an experimental scale the above-ground parts have shown excellent paper-making qualities. Zacaton grows wild over immense areas in Mexico.

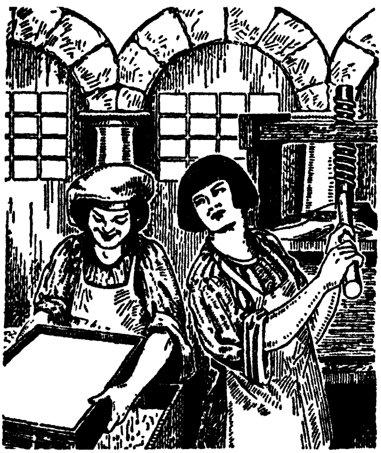

FIG. 191. — Hand Paper-Making in the Elizabethan Period; Lifting the Mold, Covered with Rag Fibers. At the right is a hand-press in operation. (Courtesy of American Writing Paper Company.)

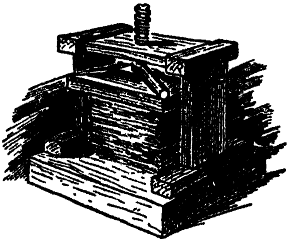

FIG. 192. — An Early Hand-Press, with Which Excess Water Was Removed from the Sheets. (Courtesy of Amercan Writing Paper Company.)

Waste Paper

Waste newspapers, magazines, etc., are collected in great quantities and used chiefly in the production of a grade of paste-board or paper-board of which the familiar shoe box is a good example. Pulped waste paper may also be used for blending with wood pulp for newsprint and for other cheap papers in which perfect whiteness is not essential. Expense of de-inking is the chief obstacle to a more extensive use of waste paper.

3. PAPER-MAKING

Hand-Making of Paper

Early paper was wholly hand-made. Like most manual processes, hand paper-making is slow, lengthy, and expensive, but it yields an extremely high-grade product. Relatively small quantities of hand-made paper are still produced. The pulp, properly thinned with water, is run into a vat and dipped out in a mold (Fig. 191). This mold is essentially a woven-wire screen bearing a slightly raised pattern which forms the water-mark of the finished paper. Intertwining and felting of the suspended fibers is aided by a dextrous lateral motion or "shake" as the screen drains. When sufficiently drained, the mold is reversed and the moist sheet taken out on a felt. Several sheets of paper and felt are thus alternated. The mass is then pressed to partial dryness (Fig. 192). After removal of the felts the sheets are again pressed and dried. Then they are sized and finished.

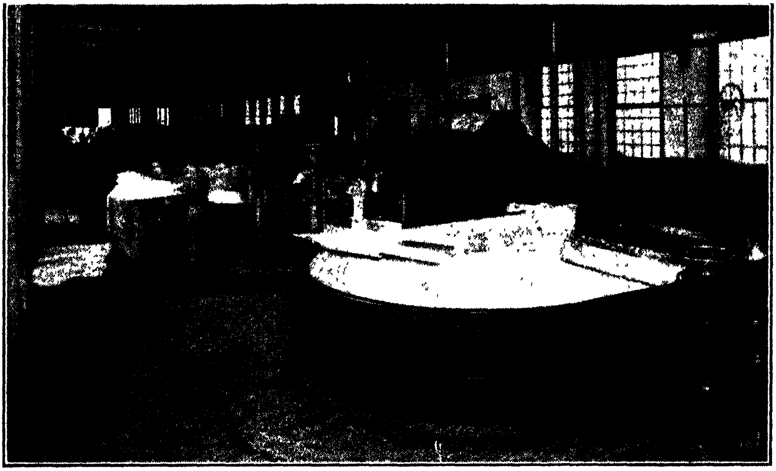

FIG. 193. — Paper Manufacture: the Beater. This machine is handling cotton rags which have undergone a number of cleaning, dusting, boiling, and washing processes. Here they are being cut and frayed into fine fibers while rosin, size, alum, and color are added. From this machine they go to the Jordan or refining engine. (Courtesy of American Writing Paper Company.)

Machine-Making of Paper

Machine-making of paper (Figs. 193, 194, 195) is a large-scale process which can be advantageously accomplished only in extensive plants with massive and costly machinery. The pulps

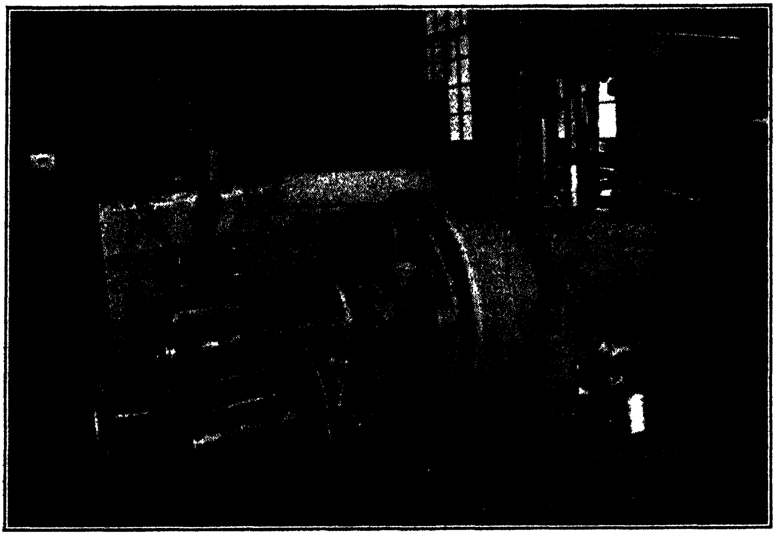

FIG. 194. — Paper Manufacture: the Jordan or Refining Engine. The large conical shell is lined with steel or bronze bars set lengthwise. A conical plug with similar bars fitted into the shell rotates at high speed and the stock passing through the two sets of bars is cut fine. (Courtesy of American Writing Paper Company.)

FIG. 195. — Paper Manufacture: The Fourdrinier or Paper Machine. The diluted stock from the Jordan passes first through screens of bronze plates with narrow slots which pass the fibers but hold back knots and refuse; from this screen the stock flows on to a fine sieve where the water drains and the fibers are left behind in a felted sheet. Deckel-straps at the edges prevent overflow, and a dandy-roll imprints the water-mark. The paper passes on to drying-drums. (Courtesy of American Writing Paper Company.)

used are usually, though not invariably, prepared wholly or in part in other departments of the same establishment. They are thoroughly blended in huge vats by a process which resembles egg-beating on a gigantic scale. Into the mixture is introduced a blue dyestuff which counteracts the natural slight yellow of the paper. Alum, sizing, and bleaching materials are also added. The mixture, suspended in water, is run into a Fourdrinier machine, which receives it upon a moving belt of finely woven copper screening. Part of the water drains, and more is removed by suction-boxes over which the belt moves. Width of sheet is adjusted by an endless rubber strap, the deckel, at each side of the screen; this also prevents the pulp from flowing over the sides. The forming paper passes off the screen between rollers; thence to a moving woolen belt which carries it through a series of press-rolls. Water-marks are imparted by a patterned screen cylinder called the dandy-roll. The paper is further dried by passage over a series of internally heated rolls. The best papers are loft- or air-dried for several days, after which they are polished by a series of calendar rolls. Super-calendared papers get additional surfacing treatment with gelatine and alum. Coated papers are surfaced with a mixture of clay and casein. Coated papers are used particularly for printing illustrations and reproductions of photographs in which all possible detail is desired.

Localization of the Paper Industry in the United States and Canada

Paper-making on this continent is said to have been established near Philadelphia in 1690. Early American paper was made chiefly of rags; straw and similar materials were used for the cheaper grades. The pulp-grinding process was discovered in Nova Scotia in 1838 and, independently, in Germany in 1840. It was not introduced into the United States till 1866, over a decade after the introduction of the English soda-pulping process. The first sulphite mill in the United States was built in 1887.

The rapid development of the ground-wood and chemical pulping processes, particularly the former, came coincidently with sudden increase in journalistic demands owing to rapid increase in population and extension of settlements. The lumber industry, with portable saw mills, can readily follow sources of supply, but bulky and expensive paper mills can be profitably established only where constant flow of material may be expected for a long time to come. The map (Fig. 196) is from a recent survey of the pulp and paper industries of the United States and Canada. The pulp industry, in particular, is still bound quite closely to the regions

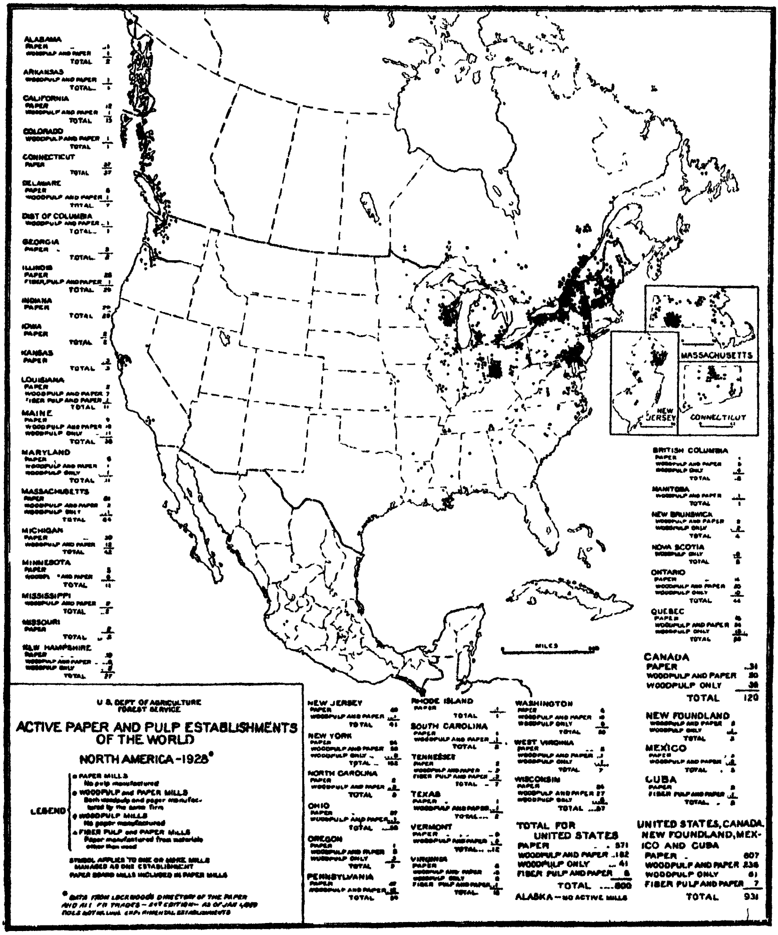

FIG. 196. — Active Pulp and Paper Establishments of the United States and Canada. Total for United States, Canada, Newfoundland, Mexico, and Cuba: Paper, 607; wood pulp and paper, 236; wood pulp only, 81; fiber pulp and paper, 7. (Data from Lockwood's *Directory of the Paper and Allied Trades*, as of Jan. 1, 1929; courtesy of United States Forest Service.)

of its first development. Rivers—such as the Connecticut, the Penobscot, the Kennebec, and the St. Lawrence and its tributaries—have been used both as power sources and as means of transportation for timber cut at forested headwaters and floated down in spring flood-time. The problem of supply grows yearly more acute, and there has been considerable recent development in the Pacific Northwest. Unfortunately, the Douglas fir, so valuable as a source of lumber, is too pitchy for advantageous pulping by the mechanical and sulphite processes.

CHAPTER IX

FOOD PRODUCTS: CEREALS AND ALLIED CROPS

1. THE NATURE OF FOODS

Foods, like many other large and inclusive categories, are not easy to define or delimit. They are substances which, after passage through digestive processes and absorption into the blood stream, liberate energy to the organism or furnish building material for it. Water and mineral salts are bodily necessities; they may be utilized constructively but do not yield energy; they are commonly considered raw materials rather than foods.

Foods and Feeds

A distinction, perhaps rather arbitrary, is drawn between FOODS and FEEDS, or FOODSTUFFS and FEEDSTUFFS; foods referring to articles of human consumption and feeds to those used by animals. Many of the same substances, of course, are used by both human beings and lower animals; when there is distinction, it is usually a matter of palatability, texture, opportunity, and often of custom and æsthetic sensibility.

Foods are either PLANT PRODUCTS or ANIMAL PRODUCTS; *if the latter, they are still products of plant metabolism* taken at second or at *n*th hand. While carbon, hydrogen, oxygen, nitrogen, and other constituents of carbohydrates, fats, and proteins are widespread in nature, only the plant can combine them in form suitable for energy-use by human beings. Despite numerous ingenious chemical researches, it seems unlikely that the supremacy of the plant will soon be disputed. Plant foods utilized by man are combinations and mixtures of carbohydrates, proteins, fats, vitamins, minerals, salts, water, and unutilized or waste materials. Meats are recombinations of the same substances, with some transformations, such as fats from carbohydrates.

Food Classes

Within the food classes considerable differences of rôle and of digestibility exist.

CARBOHYDRATES

Among carbohydrates and their relatives, starch and sugars are the principal foods; they are, in fact, the chief substances through which solar energy is utilized by man. Sugar is rarely found in plants in large quantity, but starch is very generally massed in storage organs—seeds, tubers, underground stems, and the like. It is readily digestible, nutritious, and almost tasteless. Like most reserve plant foods, it is commonly stored in thin-walled parenchyma which is readily destroyed by mastication or mechanical grinding. When foodstuff is thus readily available, its utility depends wholly or largely on presence or absence of variously flavored or physiologically active—poisonous—compounds of the plant organism. A comparatively slight recombination of the essential elements of foods—particularly of proteins—is sufficient to change valuable nutrient to deadly poison. Cellulose, lignin, and other materials of the plant framework are almost or quite indigestible in the human alimentary tract, but are used by some animals. They are far from useless constituents of foods. They make up a considerable proportion of human and herbivorous animal dejecta, and in their elimination they are credited with a sweeping, scouring, and absorbent action which aids in carrying off of other more noxious wastes. Too complete omission of "roughage" from human diet leads to incomplete waste removal and physiological disturbance.

PROTEINS

These have been previously described as highly complex nitrogenous substances, always associated with protoplasm. The most readily available protein accumulations in plants are in seeds, often in form of complex particles called aleurones, which may either be scattered or rather distinctly localized, as in the aleurone layers of cereals.

Digested proteins circulate in the blood stream as amino acids, their so-called building stones. There are sixteen or eighteen of these amino acids. Upon the nature and proportion of those present depends the protein value of a given food. Without attempting any of the complexities of a rather abstruse subject, it may be said that there are considerable differences in the biological value of different proteins. The chief protein-yielding foods of the human race are the meats of animals; generally speaking, their reorganized proteins are more easily digestible than those obtained directly from plants.

Proteins are the chief instrumentalities of tissue repair; they may likewise be converted in part into carbohydrates.

FATS

These likewise are apt to be massed in seeds. The commercial oil seeds—cottonseed, peanuts, and the like—contain large quantities; and some nuts contain over 65 per cent of fat. With fats are likely to be associated proteins, but little starch or sugar. Fats are concentrated sources of energy; carbohydrates and proteins are generally reckoned at four calories[1] per gram and fats at nine calories. These may therefore contribute largely to bodily warmth.

VITAMINS

These dietary factors are absolutely essential to the well-being of the organism and even to the maintenance of life, yet they occur in such small quantities that their nature is very difficult to determine, and they are generally better known by what they do—the effects they produce—than by what they are. Quantitative estimations of Vitamin *A*, for example, are expressed in units of one-millionth of a gram. The occurrence, nature, and rôles of vitamins have been the subjects of intensive research, and recent years have added greatly to our store of vitamin-knowledge while leaving abundant mystery still unsolved. With one exception, it is probable that all vitamins, or precursors of them termed provitamins, originate in plant tissues; some are completed or concentrated by collection in the animal. A brief list follows of those whose existence has been most thoroughly demonstrated.

Vitamin A is essential to growth in the young and to vigorous life at all ages. It tends to prevent infection and eye-troubles. It is fat-soluble. It is closely allied to carotene, a yellow pigment of plants. This occurs in green vegetables; in carrots, yellow corn, and other similarly colored plant products. Carotene seems to be converted to Vitamin *A* in the animal body, and the vitamin is found in concentrated form in cod-liver and other fish-liver oils, and in egg yolk, milk, and milk products.

Vitamin B. The vitamin once known by this name has proved to be a complex of several vitamins, which have been called B_1,

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[1] The calory is the amount of heat required to raise one gram of water one degree centigrade under certain standard conditions. It is the accepted unit of energy value of foods.

B_2, B_3, and B_4. Those best understood are vitamins B_1 and another now designated as vitamin *G*. Vitamin B_1 protects against nerve diseases such as beriberi; it promotes growth and is required by mammals for normal reproduction and lactation. Compounds of vitamin B_1 have been isolated. Vitamin B_1 is found in yeast and in the outer tissues of cereal grains; in many vegetables, in egg yolk, and in several other animal foods, such as milk, fish roe, and kidneys.

Vitamin C prevents scurvy, a disease likely to affect those whose diet is long deficient in fresh vegetables. It is required in the metabolism of bones and in tooth-formation. Its chemical constitution is known, and it has been synthesized. Citrus fruits and tomatoes are well-known sources of vitamin *C*. Dormant seeds are almost lacking in it, but it appears during the germination process. Animal foods are nearly devoid of vitamin *C*.

Vitamin D prevents rickets, a disease of metabolism often seen in infants. It is almost lacking in plant foods. It occurs in concentrated form in cod-liver oil and appears in certain oily products and in foods which are irradiated with sunlight or ultraviolet light.

Vitamin E is required for the normal reproductive function. It is found in wheat germ oil, coconut oil, and in various vegetables such as lettuce, water-cress, and the whole grains of corn and oats.

Vitamin G prevents pellagra, perhaps in connection with other factors. It seems to be formed in the growth of green plants, from which yeast and animal tissues probably derive it. Yeast, liver, and other glandular animal organs concentrate vitamin *G*, and it is found in spinach and many other green vegetables.

2. AGRICULTURAL REGIONS OF THE UNITED STATES

Crop Distribution

The crops to be discussed in the present chapter are, from viewpoints of acreages and values, the dominant agricultural plant interests of our country. The map (Fig. 197) illustrates in broad outline the principal regions of wheat, corn, and grazing and forage. It will be found useful in connection with the more detailed maps and discussions to follow.

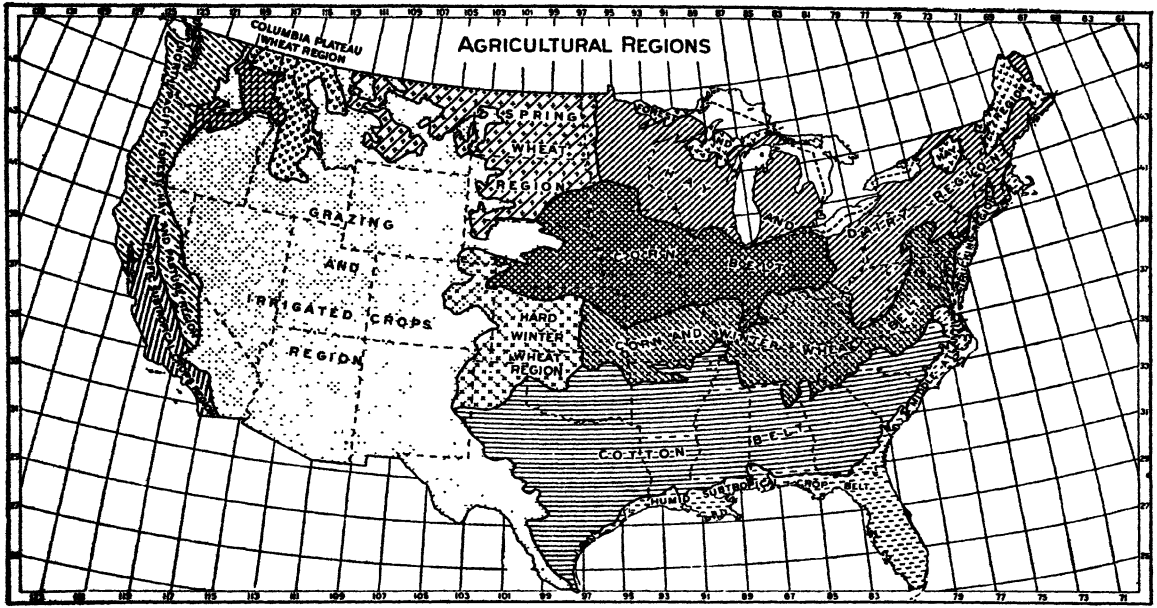
AGRICULTURAL REGIONS
COLUMBIA PLATEAU WHEAT REGION
NORTH PACIFIC FOREST, HAY AND PASTURE REGION
PACIFIC SUBTROPICAL CROPS REGION
SPRING WHEAT REGION
GRAZING AND IRRIGATED CROPS REGION
HARD WINTER WHEAT REGION
CORN BELT
CORN AND WINTER WHEAT BELT
COTTON BELT
HUMID SUBTROPICAL CROP BELT
FOREST AND HAY REGION
HAY AND DAIRY REGION
HAY

FIG. 197. — The Principal Agricultural Regions of the United States. The United States may be divided agriculturally into two parts, the East and the West. The East has a humid or subhumid climate and the land is devoted principally to crop production. The West has mostly an arid or semi-arid climate, except the North Pacific coast, and the higher altitudes in the Sierra-Cascade and Rocky Mountains, and most of the land is devoted to grazing. Each of these two parts may be divided into agricultural regions. Each of the eight Eastern regions (excluding the Forest and Hay region) is based on the dominance of a certain crop or kind of farming, which in turn is the result largely of latitude and temperature conditions. Each of the four Western regions is based principally on the use of the land for crops, for pasture, or for forest, which in turn is determined largely by altitude and rainfall conditions. (From United States Department Agriculture *Yearbook*, 1928)

3. The Cereal Grains

The Significance of the Cereals

The term CEREAL is applied to members of the Grass Family (*Gramineæ*) which are grown for their grain or fruit. Compared to the vast number of grasses, the important cereal species are few, yet if one had to assign first rank among foodstuffs to any plant group, there would be little hesitation in conferring the honor on the cereals. Particularly are they vital in temperate and colder climates because their active photosynthesis during brief growing seasons supports human life where else it could hardly survive. In the tropics, competing with a vast diversity of long-season foodstuffs not raised in northern lands, the cereals are less vitally necessary; but even in the tropics they are of major significance.

There are many reasons for the dominant position of the cereals. Besides their climatic adaptability, they are accommodating in the matter of soil-requirement. Particularly under modern machine methods, they produce great quantities of foodstuffs cheaply and with little labor. It has been estimated that the average day's labor of one man on a wheat farm produces enough food to feed the man for a year. Cereal grains are consistently high in starch, and usually rich in protein; their embryos, though small, are high in oil-content. Their outer tissues and embryos contain vitamins. The mature dried grain can be handled, transported, and stored very cheaply; with precaution against damp and insects, it can be kept indefinitely. At the present time the world seems to be suffering from the over-virtues of the cereals, though much of what passes as overproduction is really maldistribution. In the present volume, only the briefest of reference can be made to the remarkable means used by our own and other governments to relieve the world situation in wheat and in other major crops.

The Structure of the Cereal Plant

Cereal and other grass plants, though among the most familiar of vegetable objects, are as plants very slightly understood by the average individual. Some account of their structure is therefore in order.

The cereals are herbaceous annuals; rye has a perennial tendency. With the exception of Indian corn and the sorghums, which—although members of the grass family—are not very closely related to the other common cereals and which differ from them in many details of structure, their stems rarely exceed three or four feet in height. The stems, or culms, are hollow—here again the Indian corn and sorghums are exceptions—with hard nodes where the vascular bundles of the long, sharp, ribbonlike leaves join those of the culm. Culms rarely branch between the ground line and the inflorescence or flower-cluster. Underground, or just above it, the primary stem of the young plant gives rise to a tillering system (Fig. 198) of short branches which rebranch until several or many culms are formed. Through this habit of tillering the crop possibilities are increased. The long, parallel-veined leaves of the cereals sheath the stem for some distance above the node which bears them—a habit quite common among monocotyledons. Where the blade joins the sheath there is commonly a membranous appendage, the ligule, and sometimes earlike growths called auricles. These appendages fit the stem closely and tend to prevent rain from trickling between stem and sheath.

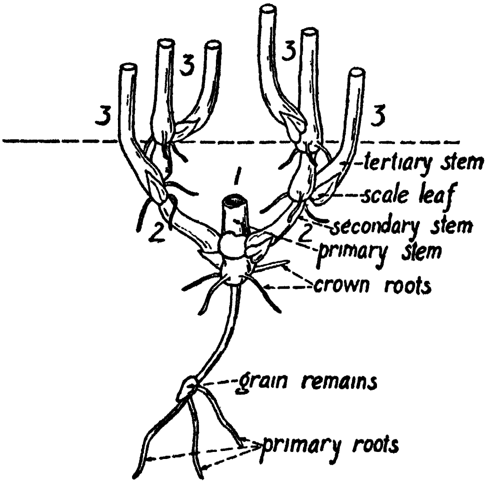

FIG. 198. — Diagrammatic Representation of Tillering in Cereals. (After Schindler, from Robbins, *Botany of Crop Plants*, P. Blakiston's Son & Co., Inc.)

INFLORESCENCE OF THE CEREALS

The branching flower-groups of grasses differ considerably in detail. To distinguish the grass floral system from various other inflorescence-types, it is called a PANICLE. The inflorescence of the oat (Fig. 199) may serve as a type for study; the variant flower and fruit characters of other cereals will be briefly discussed later.

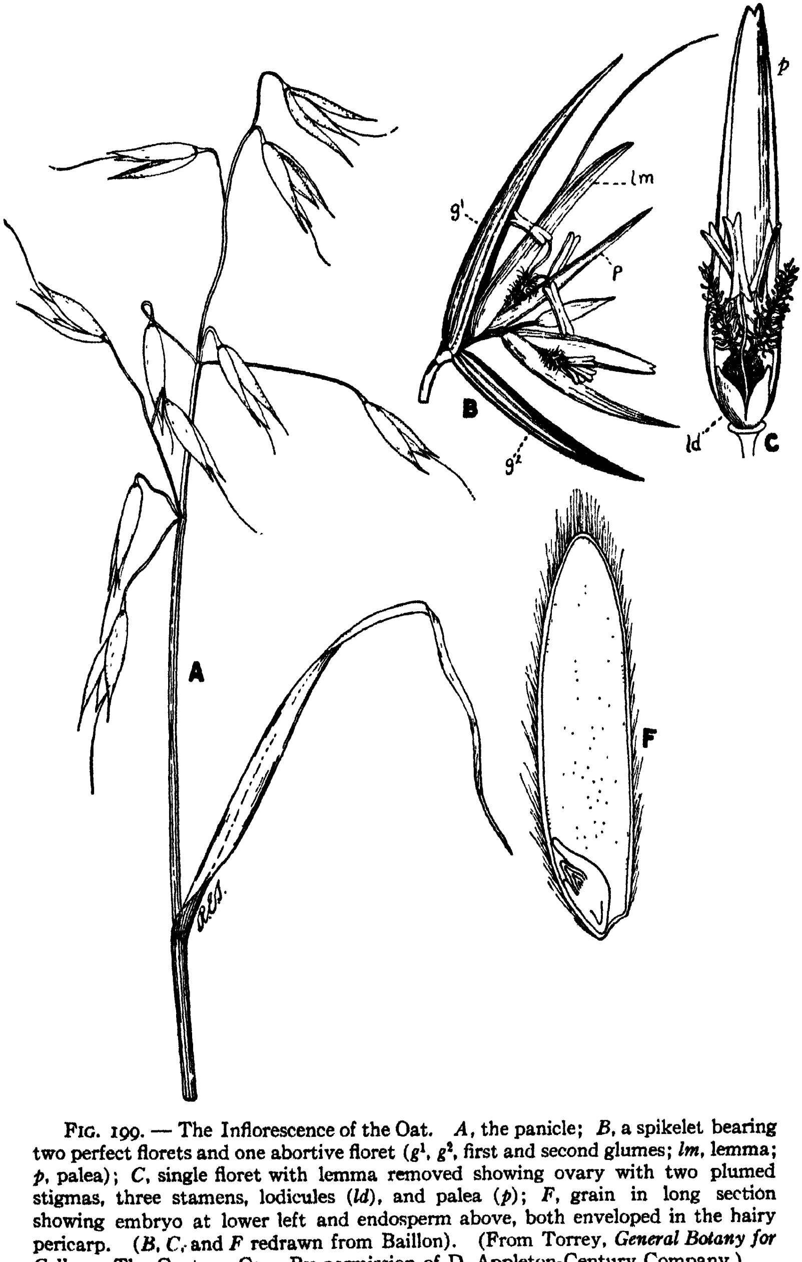

FIG. 199. — The Inflorescence of the Oat. *A*, the panicle; *B*, a spikelet bearing two perfect florets and one abortive floret (g^1, g^2, first and second glumes; *lm*, lemma; *p*, palea); *C*, single floret with lemma removed showing ovary with two plumed stigmas, three stamens, lodicules (*ld*), and palea (*p*); *F*, grain in long section showing embryo at lower left and endosperm above, both enveloped in the hairy pericarp. (*B*, *C*, and *F* redrawn from Baillon). (From Torrey, *General Botany for Colleges*, The Century Co. By permission of D. Appleton-Century Company.)

The main axis, or rachis, of the oat inflorescence breaks into several branches; and these, in many cases, into more. Upon the ultimate ends of the branchlets are the SPIKELETS. Each of the latter is a compact group of small FLORETS. At the base of each spikelet, enclosing it until it opens, are two boat-shaped structures, the GLUMES. Within the glumes a slender axis, the rachilla, bears from two to five florets. The usual number is three, and of these the third, and sometimes the second, is imperfect. The essential organs of each floret are STAMENS and PISTIL; these are enclosed in two glumelike bracts. The bract away from the rachilla is the LEMMA and that next it the PALEA. In the oat, the lemma usually bears a spine technically called an AWN. Awned cereals, in the common speech, are termed BEARDED.

Stamens of the oat are three in number, each with a long slender filament and a relatively large anther bearing abundant dusty pollen which is wind-scattered. The pistil is of two parts, or carpels, of which but one matures a seed. The bulbous ovary bears two feathery stigmas upon which the pollen germinates as preliminary to the fertilization process. Grasses, typically, are wind-pollinated, but in many of the cereals close-pollination takes place before the florets open.

At the base of the ovary are two minute structures, the LODICULES, whose swelling forces lemma and palea apart, allowing anthers and stigmas to protrude.

The fruit, or grain, consists at maturity of an ovary wall, or pericarp, which so closely invests the coats of the single seed that the structures of all seem like one integument. The seed consists of a bulky endosperm and a small monocotyledonous embryo, the latter near the point of attachment of the grain to the rachilla.

The Principal Cereals

With a few exceptions—of which maize or Indian corn is chief—the cereals are scarcely more than medium-sized and quite typical grasses, which differ from those of the field and forest chiefly in the larger size of the fruit. Their present forms have probably been developed through mutation, selection, and natural hybridization during thousands of years; the wild prototypes of most of them, in fact, are unknown.

The varied flavors of the cereal grains, as well as their flour-making and baking qualities, are largely conditioned by their different proteins. Some cereals are also rather rich in oil, which is likely to be localized in the embryo. From points of view of milling and storage the oil content increases difficulty of grinding. Since it is also likely to become rancid and to lead to insect infestation, it is a liability rather than an asset.

The stems of cereals are of some forage value when young and are more or less used for grazing, hay, and ensilage. During the ripening of the grain they become increasingly dry and woody—and less valuable. Grain stalks—corn stalks in particular—are among the major crop wastes of America. The stem waste of the small grains—straw—is used to some extent in manufacture of paper and cardboard. Some grain wastes are burned as fuel.

Cereals of principal significance in the world's economic life are WHEAT, CORN, RICE, RYE, BARLEY, and OATS. To the white race, wheat ranks first, but half the population of the globe lives chiefly on rice. Use of other grains varies widely in different regions. Grains of comparatively minor value are furnished by sorghums, millets, and various other species.

4. WHEAT

Wheat is the product of various annual members of the genus *Triticum,* chief of which is *T. sativum,* a very variable plant. It is divisible into several races, which are treated by some authors as species, and into numberless varieties.

From remotest antiquity, wheat has been the dominant cereal food of the white race. Like most plants of immemorial cultivation, it has been much modified by culture, selection, and, no doubt, mutation. The origin of the plant is uncertain; a form of Emmer, *T. dicoccum* var. *dicoccoides* (Fig. 200), which still occurs wild in

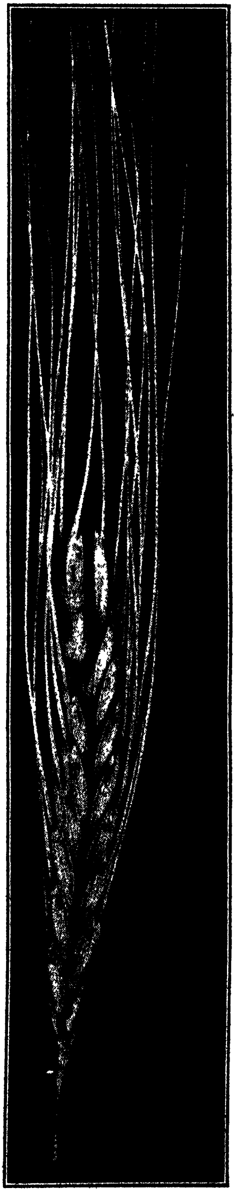

FIG. 200. — Wild Emmer of Palestine (*Triticum dicoccum* var. *dicoccoides*) as Grown in California. (Courtesy Bureau of Plant Industry.)

mountainous regions of northern Palestine and Syria, has been considered the primitive form of wheat.

The Wheat Plant

Wheat is grown both as a winter annual (winter wheat) and as a summer annual (spring wheat).

Wheat tillers freely; the root system of the mature plant proceeds from a number of subterranean nodes, filling the upper soil with a fine network which affords a very considerable absorbing surface. The culms are from two to four feet in height; those of most varieties grown in North America are comparatively stocky and stiff, affording straw which is valued for strawboard-making and for various other purposes.

The spikelets are nearly sessile and compactly arranged on a zig-zag axis. The broad glumes vary considerably in size and proportion in different races; they enclose from two to five florets, of which usually not more than two produce fruit. The bearded wheats (Fig. 201) produce long-awned lemmas; many varieties are beardless. The majority of wheats grown in northern latitudes are close-pollinated; durum wheat and the supposedly primitive wheat of Syria are usually cross-pollinated. Hot, arid environment appears to favor cross-pollination in all wheats.

STRUCTURE OF THE WHEAT GRAIN

As in the fruit of most cultivated plants, there is much variation in size and shape of grain of different wheats. The second grain of the spikelet is usually the heaviest. One hundred kernels of bread wheat usually weigh between 3.5 and 4 grams.

Ordinary wheat grains separate readily from the dried floral bracts; in emmer and some other forms the palea and lemma remain, embracing the kernel somewhat as in barley or oats. At the upper (stigmatic) end of each grain is a dense growth of fine hairs, the brush. A groove along the side adjacent to the palea marks the position of the placenta.

In the section of the kernel (Fig. 202), the following structures may be recognized; pericarp, seed-coats, nucellus, endosperm, and embryo. Positions and structures of all save the embryo are shown in the accompanying figure.

The pericarp consists of a few layers of hardened cells, whose structure has become much modified during the maturing of the grain and is difficult to make out. In the early stages of development there are two integuments; one of these is absorbed, and the other persists as a two-layered testa, which contains the coloring matter of the seed. The nucellus is a single-cell layer.

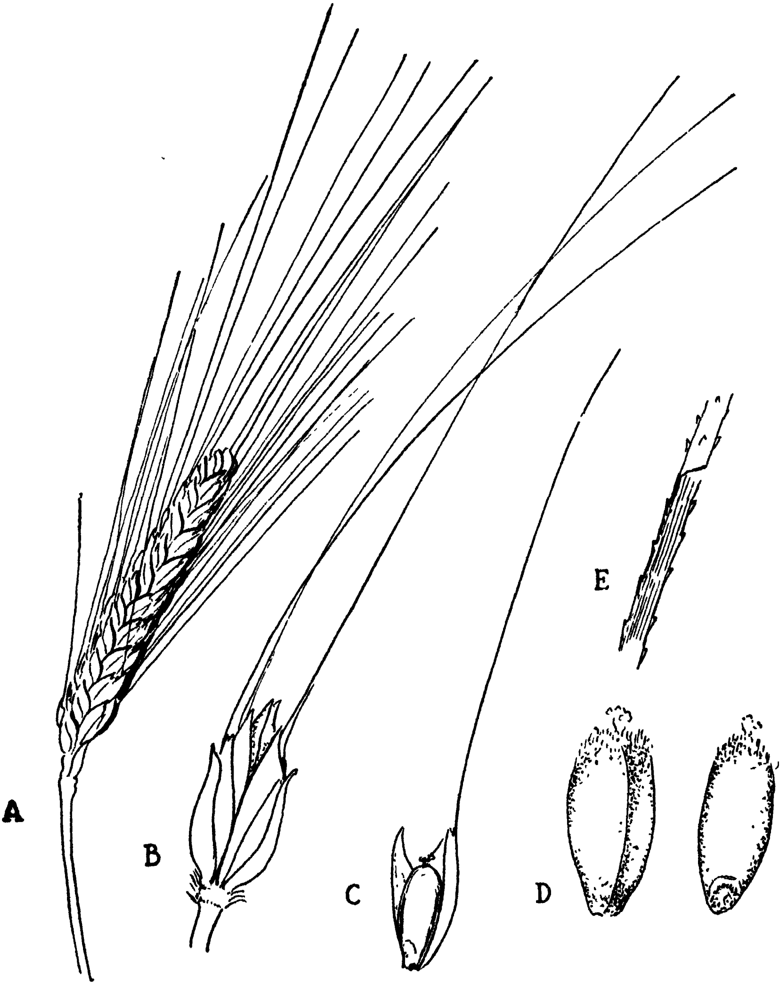

FIG. 201. — A Bearded Wheat; *A*, panicle; *B*, spikelet; *C*, floret with palea partly removed showing grain; *D*, grain; *E*, portion of awn (beard). (H. McCarthy.)

Pericarp, testa, and nucellus collectively make up the bran-coats; because of their position and toughness they are removed by the first milling processes as the familiar brown flakes of bran, to which also adhere particles of endosperm.

The bulky endosperm is of two portions, the aleurone layer and the starchy endosperm. The former is closely packed with the protein aggregates which give it its name. The starchy endosperm is made up of thin-walled storage parenchyma, in the cells of which are massed the characteristic disk-shaped starch grains. Proteins also occur in the starchy endosperm.

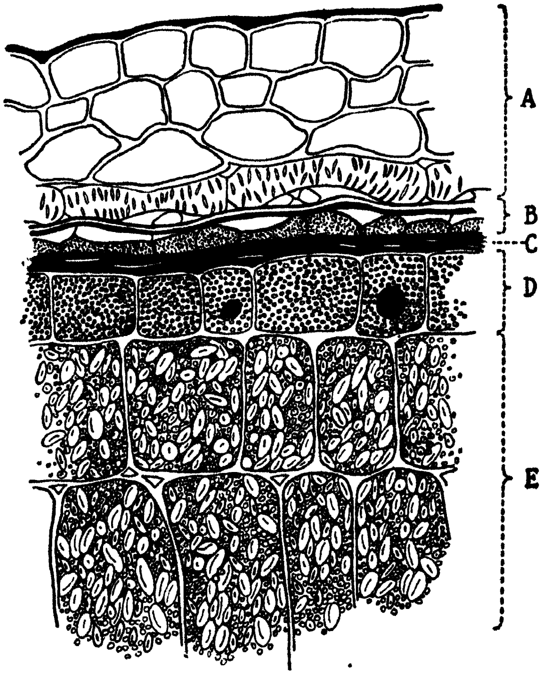

FIG. 202. — Wheat Grain in Section. *A*, pericarp; *B*, seed-coats; *C*, nucellus; *D*, aleurone layer; *E*, starchy endosperm. (E. Coffman.)

The embryo is lacking in starch, but contains protein and oil.

The relative weights of the parts of the grain are stated as follows:[1]

	Per Cent
Bran coats	8 – 9
Aleurone layer	3 – 4
Starchy endosperm	82–86
Embryo	6

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[1] W. W. Robbins, *Botany of Crop Plants* (P. Blakiston's Son & Co., third ed.), p. 109.

COMPOSITION OF WHEAT

Different wheats vary in their carbohydrate and protein content; variation is correlated with varietal characteristics and also with climatic, seasonal, and soil conditions. The so-called SOFT wheats are relatively low in protein and rich in starch; these are favored for pastry flours and the making of biscuits and crackers. HARD wheats are high in protein; from these come bread flours. Various types of wheat are mixed in carefully regulated proportions in most trade marked flours. DURUM, an especially flinty

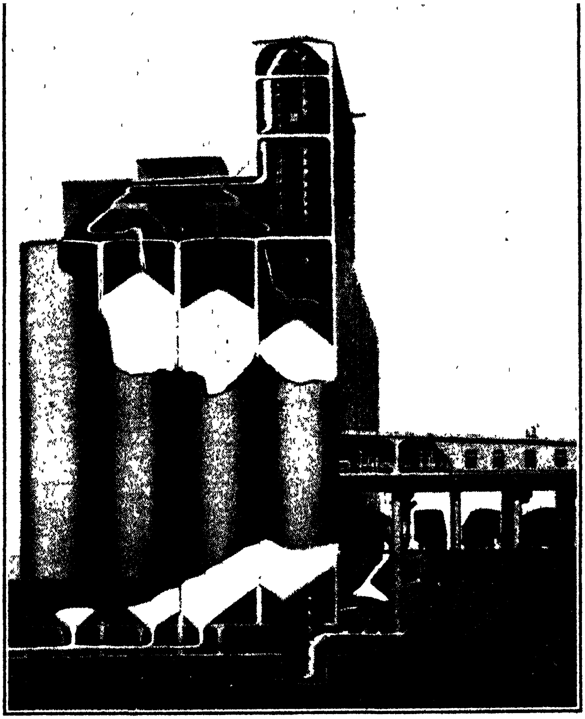

FIG. 203. — A Mammoth Grain Elevator, in Partial Section. The wheat is dropped from the cars into the scales, then lifted in cups to the very top of the building, where it is distributed by gravity and belts to the various bins. This elevator has forty-five bins, each holding 40,000 bushels, and many smaller ones. Pressure of an electric button will send streams from any or all to underground belts which carry it to the mills. (Courtesy of General Mills, Inc.)

wheat type, is chiefly used in making macaroni and other edible pastes.

The proteins of wheat are collectively known as GLUTEN. In food values, gluten does not rank particularly high among proteins. When moistened, it converts the floury mass into sticky dough. This is converted by the carbon dioxide of baking powder reaction or yeast fermentation into a light, spongy mass which holds its porous character when baked. Wheat is unequaled for light-bread making. With the exception of rye, other cereals are lacking in dough viscosity.

The Milling of Wheat

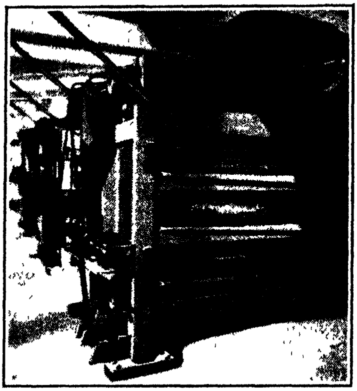

FIG. 204. — Cleaning Wheat. The separator shown above operates with an oscillating motion, the wheat being placed on successive screens of different sizes. Constant suction draws off the lighter particles. (Courtesy of General Mills, Inc.)

The thoroughly cleaned grain is stored for use in great elevators (Fig. 203). When withdrawn for milling it is moistened slightly and passed through a succession of heavy rollers. This moistening prevents the pulverization of the outer layers, which are removed in brown flakes, the bran. In addition to pericarp, testa, and nucellus, this contains most of the aleurone layer and a little starchy endosperm. Bran is rich in protein (14–18 per cent); it also runs high in vitamins. Bran and other wheat byproducts are valued feedstuff. Bran is also employed in the human dietary not only for its protein and vitamin content but for its effect as "roughage"—indigestible material which stimulates intestinal peristalsis and adds bulk to the waste-mass.

Continued rolling, sifting, and bolting divides the remainder of the grain into middlings—a granular product containing some bran—and flour, the latter chiefly from the starchy endosperm. Middlings may be reground and resifted and the fractions used in flour and feeds; great quantities are sold also as farina and under other trade names as breakfast cereals. Flour, termed

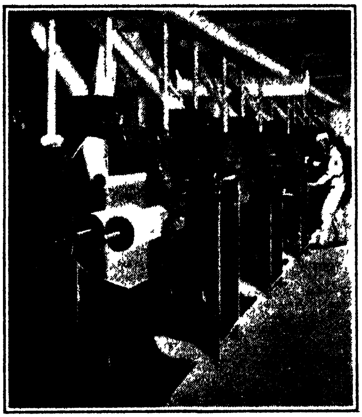

Fig. 205. — Roller Mills; the First in Sectional View. Part of the wheat passes through the rollers as many as fourteen times; first through corrugated rollers of various degrees of fineness, used to break off the brancoats, and then through smooth ones to reduce the flour to the proper fine granulation. The grinding action is obtained by revolving one of the two rollers in each mill faster than the other. (Courtesy of General Mills, Inc.)

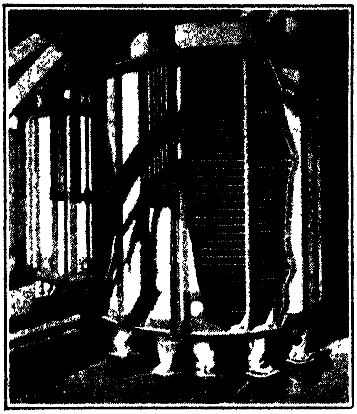

Fig. 206. — Bolting. The ground wheat "shimmies" in this machine; at the base are shown the different exits from which issue streams of flour, each one having passed through a silk bolting-cloth of different mesh. Each stream is reground, except the finest, which is sent to a revolving reel, where it is determined which part can go to the purifier for the finishing touches. (Courtesy of General Mills, Inc.)

"bread" or "pastry" flour according to the type of grain and the grades included, amounts to 70–75 per cent by weight of the grain used. Four and one-half bushels of wheat yield one barrel (196 lbs.) flour and 70 pounds of feeds. Graham flour contains the entire wheat grain, whereas "entire wheat" or "whole wheat" contains only about one-half the bran.

Throughout the milling process, the utmost care is taken to prevent the fine starchy dust of the grinding from escaping into the atmosphere. Any fine organic

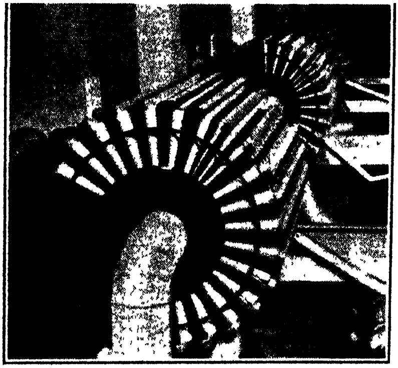

Fig. 207. — Dust Collectors. Their ingenious mechanism keeps the air of the modern flouring mill free from dust and minimizes the danger of explosion. (Courtesy of General Mills, Inc.)

dust mixed with the air forms an inflammable and even explosive mixture, and many fatal and disastrous accidents have occurred from dust explosions and fires (Fig. 208). In modern milling ingeniously devised machinery reduces these dangers to a minimum.

Centers of the milling industry of the United States are Minneapolis, St. Paul, Kansas City, and St. Louis.

Kinds of Wheat, and their Production in the United States

The official Grain Standards of the United States recognize five commercial wheat classes: HARD RED SPRING, DURUM, HARD RED WINTER, SOFT RED WINTER, and WHITE. Each class has two or three subclasses and each subclass five numerical grades.

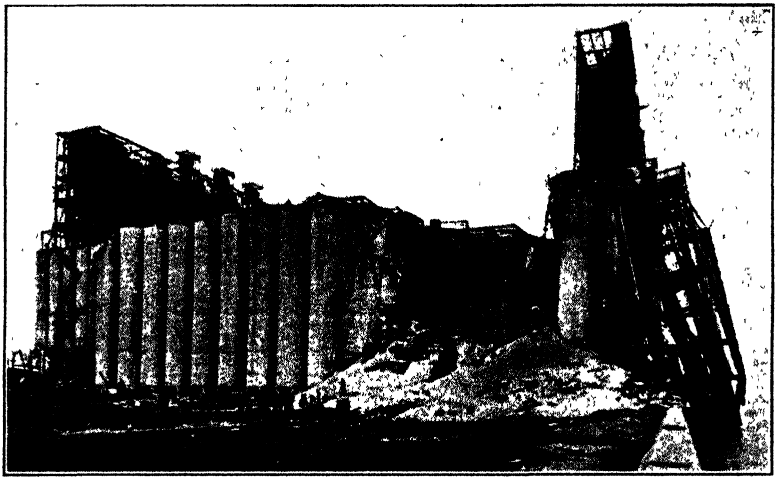

FIG. 208. — Results of a Grain-Dust Explosion in an Elevator. Six men were killed and property and grain damage was $4,000,000. (Courtesy Bureau of Chemistry and Soils.)

Governmental standardization; the exacting demands of millers; extensive researches into quality, yield, and environmental adaptibility coupled with breeding and introduction experiments; and the prevalence of black stem rust are among the factors which have tended to concentrate production within a few of a vast number of wheat varieties. There were in 1929, 252 recognized and registered wheat varieties, but many of these were grown but sparingly and locally. In 1919 there were twelve varieties grown to the extent of over 1,000,000 acres each, and in 1924, seven varieties. The average yield per acre in the United

States is about fourteen bushels. Estimated wheat yields for certain years are tabulated below.

TABLE VI

WHEAT PRODUCTION, EXPORTS AND IMPORTS IN THOUSANDS OF BUSHELS, FOR YEARS SHOWN

YEAR	ACREAGE HARVESTED	AVERAGE YIELD PER ACRE	PRODUCTION	FOREIGN TRADE, INCLUDING FLOUR, YEAR BEGINNING JULY [1]			
				Domestic exports [2]	*Imports* [3]	Net exports [4]	
						Total	*Percentage of production*
	1,000 acres	*Bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*Per cent*
1890	34,048	11.1	378,097	109,017	586	109,054	28.8
1909	44,262	15.8	700,434	89,173	845	88,465	12.6
1910	45,681	13.9	635,121	71,338	1,175	70,164	11.0
1911	49,543	12.5	621,338	81,891	3,445	78,447	12.6
1912	45,814	15.9	730,267	145,159	1,304	143,938	19.7
1913	50,184	15.2	763,380	147,955	2,402	146,306	19.2
1914	53,541	16.6	891,017	335,702	728	335,162	37.6
1915	60,469	17.0	1,025,801	246,221	7,254	239,591	23.4
1916	52,316	12.2	636,318	205,962	24,960	181,067	28.5
1917	45,089	14.1	636,655	132,579	31,215	102,775	16.1
1918	59,181	15.6	921,438	287,402	11,289	276,615	30.0
1919	*73,099*	*12.9*	*945,403*	....	....	....	....
1919	73,700	12.9	952,097	222,030	5,511	216,671	22.4
1920	62,358	13.5	843,309	369,313	57,682	312,625	37.5
1921	64,566	12.7	818,964	282,566	17,375	265,590	32.6
1922	61,397	13.8	846,673	224,900	20,031	205,079	23.6
1923	56,920	13.3	759,506	159,880	28,079	131,892	16.5
1924	*50,862*	*15.7*	*800,877*	....	....	....	....
1924	52,460	16.0	840,091	260,803	6,201	254,695	29.5
1925	52,441	12.8	668,982	108,035	15,679	92,669	13.7
1926	56,815	14.7	833,544	219,160	13,264	205,994	24.8
1927	59,628	14.7	874,633	206,259	15,734	190,578	21.7
1928	59,309	15.6	926,130	163,687	21,442	142,301	15.6
1929	*62,000*	*12.9*	*800,649*	....	....	....	....
1929	62,671	13.0	812,573	153,245	12,956	140,361	17.3
1930	61,140	14.0	857,427	131,475	19,059	112,435	13.1
1931	55,344	16.3	900,219	135,797	12,886	123,774	13.7
1932 [5]	55,177	13.2	726,831	....	....	....	....

From United States Department of Agriculture *Yearbook*, 1933. Bureau of Agricultural Economics. Production figures are estimates of the Crop-Reporting Board, revised 1919 to 1928. Italic figures are census returns.

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[1] Compiled from Commerce and Navigation of the United States, 1890–1917; Foreign Commerce and Navigation of the United States, 1918; Monthly Summary of Foreign Commerce of the United States, June issues, 1919–1926; January and June issues, 1927–1932. Wheat flour converted to terms of grain on the following basis: 1890–1908, 4.75; 1909–1917, 4.7; 1918–19, 4.5; 1920, 4.6; 1921–1932, 4.7.

[2] Includes flour milled from imported wheat.

[3] Includes wheat imported for milling in bond and export.

[4] Total exports (domestic plus foreign) minus total imports.

[5] Preliminary.

Hard red spring wheat is grown chiefly in the Dakotas and Minnesota, where winters are too severe for winter wheats. About twenty varieties are of commercial importance. Of the 1924 hard red spring acreage, 85.4 per cent was of Marquis, which, among all wheat varieties, ranks second to Turkey. The hard winter and spring wheats are chiefly used in bread flours.

Durum wheats are very hard, long-bearded spring wheats, whose principal use is described below. They are mostly grown in the Dakotas. Kubanka is the chief variety; about 75 per cent of the crop of 1924 was reported simply as durum. Durum wheats are considered especially resistant to stem rust and drought.

Hard red winter varieties form the largest class of American wheats. They are widely scattered; the chief areas are in the Great Plains States of Kansas, Nebraska, and Oklahoma. Turkey (Kharkof) is the leading variety, with about 70 per cent of the acreage. Kanred comes next with 21 per cent.

Soft red winter wheats make up the chief class east of the Mississippi Valley; they are also grown rather extensively in the Pacific Northwest. Far more than the Mississippi Valley States, the older settled Eastern regions are characterized by diversified farming, which is favored by the well-distributed rainfall and lack of new land for large-acreage productions. Wheat acreage in the soft red winter region decreased 8 per cent between 1919–1924, this being the largest decrease shown in any wheat group. Of fifty-eight varieties listed for 1921, Fulcaster, Fultz, and Poole led with a collective total of about forty-four per cent. Soft wheats are chiefly used for pastry flours, biscuits, bakery products, and crackers.

White wheats are now the smallest class. They include both winter and spring varieties and are mostly grown in the Pacific States and in the States bordering the Great Lakes. They are used for pastry, for breakfast foods, and for blending with other wheats in bread flours.

MACARONI

Fine granular middlings of the highly glutinous durum wheat form the basis of an important group of wheat-paste products extensively utilized in southern Europe and now largely manufactured in the United States. The middlings—semolina—are worked into a heavy viscous dough which, under great pressure, is forced through metal dies which shape the product. Holes in dies making macaroni and spaghetti are centered by metal pins, which make the familiar "hole in the macaroni." As they emerge from the

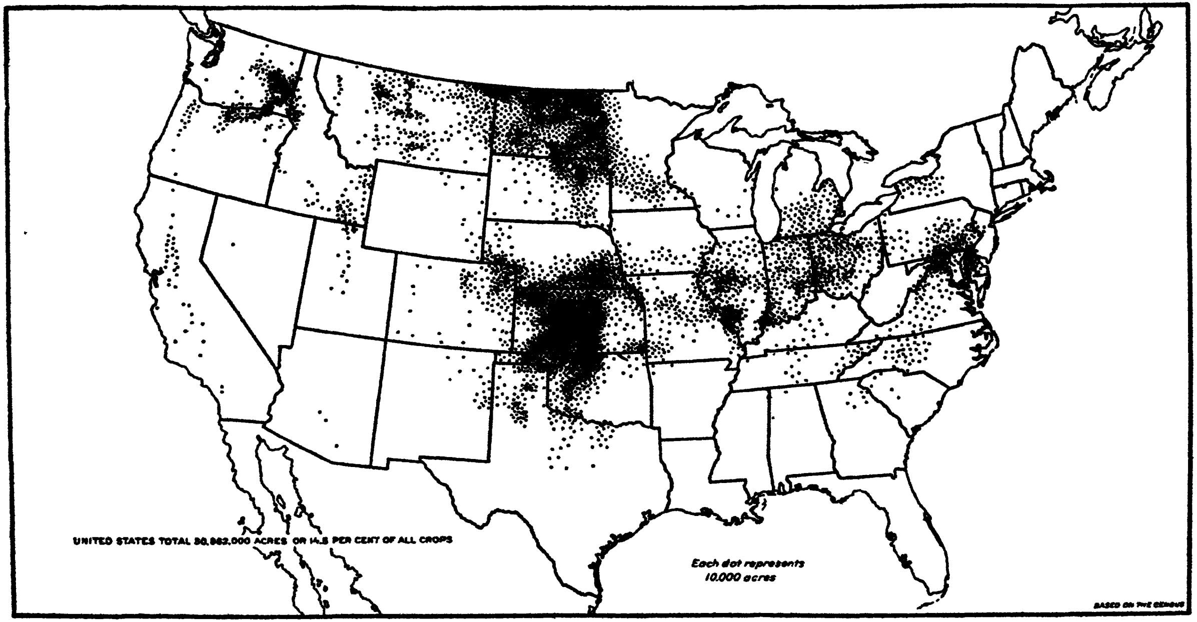
UNITED STATES TOTAL 50,862,000 ACRES OR 14.5 PER CENT OF ALL CROPS
Each dot represents 10,000 acres
BASED ON THE CENSUS

FIG. 209. — Wheat Acreage of the United States, 1924. The United States produces about one fifth of the world's wheat, as compared with three fifths of the world's corn and cotton. The wheat crop of the United States, measured in bushels, is usually from one fourth to one third of the corn crop. Nearly three fourths of the wheat crop was grown in nine States in 1924. Kansas was the leading State, as usual, with North Dakota second. The area extending eastward from Kansas to New York and Pennsylvania grows chiefly winter wheat, while in Minnesota, the Dakotas, and eastern Montana, the crop is practically all spring-sown wheat. In central Montana, Idaho, Washington, Oregon, and California both winter and spring varieties are grown. (From United States Department of Agriculture *Yearbook*, 1928).

dies, the strands are cut in lengths, hung on racks, and carried into curing rooms where they are dried under carefully controlled conditions. Noodles contain a small proportion of egg yolk; the paste of these is rolled thin and passed through shredding and folding machines. Only durum wheat pastes can be dried in the tubular and wirelike forms of macaroni, spaghetti, and vermicelli; other wheats will not bear their own weight.

The World's Wheat Production

Although great populations of the Orient and Africa use very little wheat, while large European groups utilize rye and some barley and oats in breadstuffs, wheat holds a dominant position in the agricultural economics and the trade of the world.

The principal wheat-producing nations are United States, Russia, Canada, France, India, Argentina, Italy, Germany, and Australia. These usually rank in about the order named. Canada, Argentina, Australia, and the United States are on a large-export basis. Before the World War, Russia was also an important wheat exporter. The revolutionary debacle in that country and the slow resumption of normal commerce due to Soviet reorganization took Russia out of the world wheat market for many years. Meanwhile, spurred by patriotic appeal and by high prices of foodstuffs, wheat production increased elsewhere. War demands especially stimulated production in the great exporting nations. Rapid development of power machinery, especially of the combine, which cuts and threshes at one operation, enhanced output and reduced the man and horse-power formerly needed. Extension of dry farming in America, the development of short-season varieties suitable to Canadian and to high-altitude culture, and the development of new wheat regions—likewise exploited by power machinery in Australia and Argentina—further increased supplies. War exigencies reduced production in Europe about one-fifth. At the end of the war this loss had been more than made up by increased production elsewhere.

When the conflict was over, impoverished European countries stimulated wheat production both for the rehabilitation of their own agriculture and because they lacked money to import wheat. Thus European wheat culture rapidly returned, while production elsewhere showed, in total, more increase. Save for England, Belgium, and Holland, European nations also raised high and designedly protective tariffs against outside wheat. As a last catastrophic factor, in 1931, Russia reappeared in the world market with large offerings of wheat at prices far below cost of

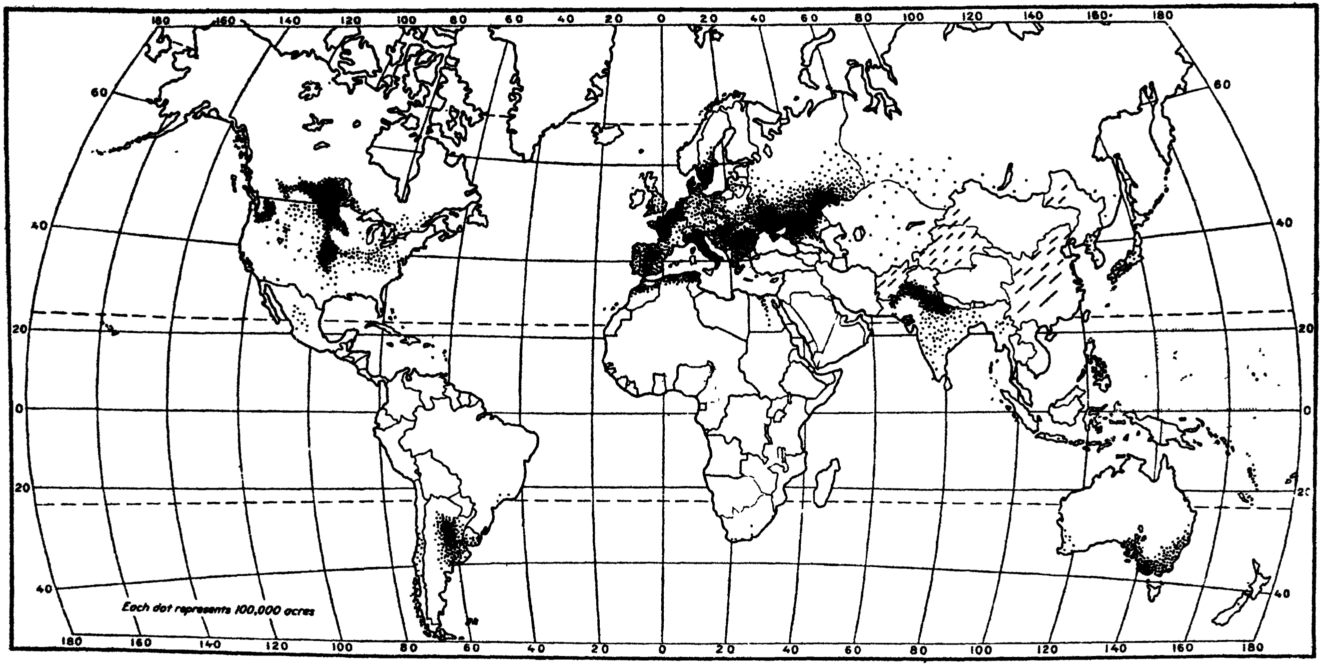

FIG. 210. — World Wheat Acreage, 1931. (From Bureau of Agricultural Economics, United States Department Agriculture.)

raising elsewhere—and, it was strongly intimated, also below cost of production in the Soviet realm.

In the United States, war prices had afforded handsome profits both to producers and speculators. Under post-war conditions, wheat production became rapidly less and less remunerative. Acreage, nevertheless, was not only maintained, but increased under a falling market. Throughout most of the wheat region, that grain is the principal cash crop, and in many localities it is the only one. As the farmer's margin of profit disappeared, he strove to maintain his income by growing more wheat.

TABLE VII

WHEAT, WORLD PRODUCTION IN MILLIONS OF BUSHELS FOR YEARS SHOWN

CROP YEAR	*World production, excluding Russia and China*	*Northern Hemisphere production excluding Russia and China*	*European production, excluding Russia*	SELECTED COUNTRIES						
				Russia [2]	*United States*	*Canada*	*India*	*Argentina*	*Australia*	*France*
1909–10	2,819	2,554	1,240	846	700	167	285	131	90	359
1919–20	2,809	2,504	900	.....	952	193	280	217	46	187
1920–21	2,968	2,612	949	320	843	263	378	156	146	237
1921–22	3,177	2,795	1,222	205	819	301	250	191	129	323
1922–23	3,203	2,845	1,044	243	847	400	367	196	109	243
1923–24	3,519	3,087	1,257	419	760	474	372	248	125	276
1924–25	3,126	2,715	1,058	472	840	262	361	191	165	281
1925–26	3,380	3,013	1,397	782	669	395	331	191	115	330
1926–27	3,496	3,045	1,216	914	834	407	325	230	161	232
1927–28	3,671	3,198	1,275	785	875	480	335	282	118	276
1928–29	4,011	3,431	1,410	807	926	567	291	349	160	281
1929–30	3,561	3,194	1,450	694	813	305	321	163	127	337
1930–31	3,813	3,312	1,362	989	857	421	391	232	214	228
1931–32	3,771	3,297	1,434	.....	900	304	347	220	190	264
1932–33 [1]	3,760	3,260	1,499	.....	727	431	337	231	200	331

From United States Department of Agriculture *Yearbook*, 1933. Bureau of Agricultural Economics. Both acreage and production figures refer to the year of harvest. Harvest of the Northern Hemisphere countries are combined with those of the Southern Hemisphere which immediately follow; thus for 1932–33 the crop harvested in the Northern Hemisphere countries in 1932 is combined with the Southern Hemisphere harvest which begins late in 1932 and ends early in 1933.

[1] Preliminary.

[2] Includes all Russian territory reporting for years named.

In no long time, the profit margin disappeared entirely; wheat growing, the nation over, was unprofitable for a series of years; yet producers, anchored to land with its rapidly decreasing values, seemed to have no recourse save to continue to plant wheat in the hope that the coming season would see the turn of the tide.

In 1928–1929 a record-breaking world wheat crop left an unused stock of some 850,000,000 bushels—about 350,000,000 bushels more than the usual carry-over at a season's end. In subsequent seasons, the world-crop has not substantially exceeded consumption, but the 1928 surplus has been carried on, in effect, from year to year, with resultant disorganization, not only of the wheat industry, but of the production-and-price system of all the cereals, of livestock, and with disaster to the entire economic life of the world. As the surplus wheat has been concentrated chiefly in the United States and Canada, these nations have been the chief sufferers from the ruinous excess of wheat.

In the summer of 1931, wheat sold for what was then an all-time low in Liverpool, principal wheat market of the world. The United States government, embarked in a vain effort to stabilize price, held 250,000,000 bushels of grain which it could not dispose of save to the further ruin of a wrecked market. Meanwhile, millions of people throughout the world were on the verge of starvation and beyond it, while on Western ranches American farmers burned wheat for lack of money to buy other fuel.

At the beginning of the century, predictions had been made that within thirty years the world's wheat demands would have so far outranged production as to incite a "scramble for the wheat crop" which might well result in world-wide war or famine. At the end of the thirty years, the principal producing nations were seriously embarrassed by their surpluses, and no solution to the enigmatic situation seemed in sight.

WHEAT CROP RESTRICTION

In 1933 the United States Government began a determined effort to restrict domestic wheat production. Anything like a detailed picture of the federal program and its implications is impossible here. In substance, the government agreed to pay wheat growers to reduce their acreages by a stipulated percentage, and undertook to raise the necessary funds by a processing tax on milled wheat. This policy was designed to be developed and maintained over an undetermined series of years.

Of greater promise for the adjustment of the world wheat situation appeared a two-year agreement signed by an international wheat conference in London during August, 1933. That the adjustment of the problem was beyond the power of any single nation had long been obvious, but similar conferences held during 1931 had reached no agreement. The conference of 1933 first convened at Geneva, and its meetings were continued in London in connection with those of the World Economic and Monetary Conference.

The original participants in the wheat conference were representatives of the four chief wheat exporting nations—the United States, Canada, Australia, and Argentina. Other producing nations were later drawn in and, when the exporting countries had reached substantial agreement upon policies, importing nations were invited to participate.

The agreement on the part of exporting nations was designed to reduce either acreage or exports of each 15 per cent during 1934-1935. World exports for that year were tentatively fixed at 560,000,000 bushels—about 50,000,000 bushels below the actual movement during 1932-1933—and this amount was allocated as follows: Canada, 200,000,000 bushels; Argentina, 110,000,000 bushels; Australia, 105,000,000 bushels; United States, 47,000,000 bushels; and the remainder chiefly between the Danubian nations of Europe and Russia.

The wheat importing nations, for their part, signed an agreement whose purport is expressed in the following excerpt from the document:

> "The intention of this agreement is that the importing countries will not take advantage of a voluntary reduction of exports on the part of the exporting countries, by developing their domestic policies in such a way as to frustrate the efforts which the exporting countries are making, in the common interest, to restore the price of wheat to a remunerative level."

In particular, they agreed to cease efforts to extend their own wheat productions, and gradually to ameliorate or remove tariff barriers and other restrictive measures as the world-wheat price should increase.

Enforcement means, naturally, had to be left to the domestic policies of signatory nations, but a permanent Wheat Advisory Committee was created further to study the situation and to formulate continuative policies. On this were placed seven representatives from exporting countries and a similar number from importing nations.

Only time can reveal the future success of these national and international efforts to control the wheat situation, and nothing but experience can indicate whether or not the world wheat agreement marks a positive step toward international concord in crop production and trade agreement.

5. OTHER SMALL GRAINS

Barley

Barley is the product of *Hordeum distichon* and *H. vulgare,* each of which may be subdivided into numerous subspecies and varieties. *Hordeum* includes about twenty species, several of which, such as *H. murinum* (Wall Barley), *H. jubatum* (Squirrel-tail), and *H. gussoneanum* (Alkali Barley) are widespread and rather obnoxious annual weeds. Another wild species, the Asiatic *H. spontaneum,* has been considered the progenitor of the modern barleys of cultivation.

THE BARLEY PLANT

In habit barley somewhat resembles wheat, to which, in fact, it is rather closely related. The culms are usually less than three feet in height. The inflorescence, like that of wheat, is a close, heavy spike. Three one-flowered spikelets occur at each joint of the rachis. In Two-rowed Barley (*H. distichon*) (Fig. 211), the lateral spikelets produce no grain. In Six-rowed Barley (*H. vulgare*) (Fig. 212), each floret is fertile; the alternating groups of spikelets form six equidistant and distinct rows.

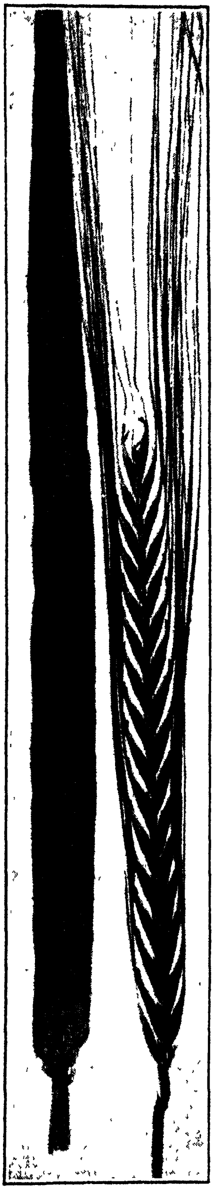

FIG. 211. — Two-Rowed Barley. (Courtesy of University of California College of Agriculture.)

The glumes of barley are narrow and bristlelike, placed at the sides of the florets and simulating a bristly involucre at each joint of the rachis. The lemmas are broad; in most varieties they terminate in long awns which render barley heads among the most conspicuously bearded of the cereals. While the florets usually open briefly, barley is almost invariably close-pollinated. As in oats, the mature grain is, in most varieties, invested by a hull consisting of the lemma and palea. The floret is also characterized by a short rachilla which remains as a kind of bristle behind the palea in the hulled barleys.

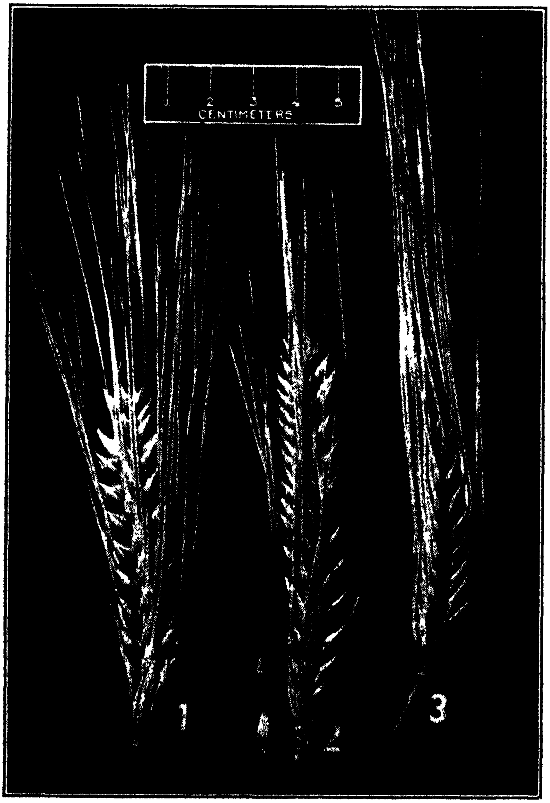

Fig. 212. — Three Barley Varieties. (Courtesy of University of California College of Agriculture.)

The older barley varieties grown in the United States possess rough, barbed awns; the heads are disagreeable to handle and to thresh. In recent years, Russian smooth-awned barley has been introduced by the United States Department of Agriculture, and hybridization with American barleys has yielded several valuable smooth-awned sorts which are now widely cultivated. These have been an important factor in the increase of barley production for feedstuff. It has been estimated that half the barley acreage of the United States is now of smooth-awned sorts.

The details of barley kernel structure are quite similar to those of wheat. The aleurone region usually consists of three cell-rows. The endosperm varies in consistency and appearance from floury to various degrees of translucency with increasing amounts of protein. Two-rowed barleys run higher in protein than the six-rowed kinds.

An unusual number of colors are exhibited by ripened barley, including white, red, brown, and black.

ENVIRONMENTAL RELATIONS AND CULTURE

Barley is cultivated through a wide range of latitude and altitude. The antiquity of its cultivation is shown by remains found in the Stone Age deposits of Switzerland. While barley is ranked as a hardy grain, it does not thrive in the north as a winter annual and is chiefly sown in the spring. Areas of production in the United States formerly centered about the brewing regions and in recent years have shifted westward to the north and west of the Corn Belt, where barley is now an important crop. In 1927, Minnesota, North Dakota, and South Dakota led in barley production. The average yield of barley in the United States is about 33.5 bushels per acre.

USES OF BARLEY

Barley has had a great variety of uses. Pliny considered it the most ancient food of mankind, and for centuries it was an important human food. Its lack of gluten militates against its use in modern bread. Its principal use in the present day dietary is in soups and infant foods.

Barley is the principal grain used in malting for the brewing of beer and allied beverages and for malt extracts. Great quantities are malted in Europe, and, considerable malting barley is exported from the United States, particularly from the San Joaquin Valley of California.

The prohibition of alcoholics resulted in lessening of barley acreage in certain areas in the United States, but because of the growing use of this grain as a feedstuff the total yield has in recent years increased. From 50 to 75 per cent of the annual crop of the United States is now fed locally to stock. Exports run 10–15 per cent; 2 to 3 per cent is used for malting, and the remainder for sowing and miscellaneous uses which include the making of yeast and vinegar. The hooded barleys, beardless and short-bearded varieties, are much grown for hay and pasturage, especially at high altitudes where the growing season is short.

Malting.—Prior to 1920 about one third of the barley crop of the United States (about 60,000,000 bushels annually) was used in the brewing of fermented beverages and a few minor products. Under prohibition, legal brewing was confined to near beers and malt tonics; there was also some production of canned malt extract. Small quantities of malted grain are employed in breakfast cereals. In 1925, production of about $24,000,000 worth of malt was reported, about 50 per cent of which was made in Wisconsin. Other kinds of grain may be malted, but malt, in ordinary usage, refers to barley which has been partially germinated and then dried.

In malting, the grain is steeped from forty-eight to seventy hours in water at about 55 degrees Fahrenheit. During this period the water is changed two or three times to promote aëration and check bacterial action. The steeped grain contains about 60 per cent moisture. It is spread on floors and turned and aërated for about twelve days. During this period the enzymic processes of germination go on actively; the starch of the endosperm is changed in part into sugars and dextrins; translocation of these into the developing embryo begins. Proteins share in the enzymatic changes. Three or four roots appear and the shoot grows about three fourths the distance up the back of the grain. During the last four days on the floor the malt is dried somewhat and the growth of the embryo stops. Drying is completed in kilns, slowly at first, and then at about 160 degrees Fahrenheit until the moisture content is reduced to 2 per cent. Sprouts are removed and may be used as feedstuff. The quality of malt is said to be improved by storage.

For malting European brewers prefer two-rowed, low protein barleys, while six-rowed varieties are chiefly used in America.

WORLD PRODUCTION OF BARLEY

The annual barley harvest is usually something over 1,500,000,000 bushels. In pre-war years Russia led with a crop between 300,000,000 and 600,000,000 bushels. In recent years estimates of the Russian crop have only once exceeded 250,000,000 bushels, and the leading place has been taken by the United States, whose maximum crop, of 1927, was 356,868,000 bushels. Other large barley-producing nations are India, Germany, Spain, Japan, and Roumania, in approximately the order named.

Rye

Rye is the grain of *Secale cereale* (Fig. 213), an annual grass with more or less perennial tendency like its supposed ancestor, *S. montanum* of the mountains of central Eurasia. Apparently rye is of more recent domestication than wheat and barley, for remains of it have not been found with those of the other grains among the relics of early Asiatic civilizations.

FIG. 213. — A Rye Field in Georgia. (Courtesy of Bureau of Plant Industry.)

THE RYE PLANT

Secale cereale is a vigorous grass, sometimes reaching a height of six feet, with slender but tough culms and long leaves. Panicles are narrow, usually four-ranked, somewhat resembling those of barley. The whole plant has a bluish aspect. Spikelets are three-flowered, maturing the two lowest grains. Lemmas are long-awned. Rye, unlike other common cereals save Indian corn, is cross-fertilized. The grain (Fig. 214) is somewhat darker in color and more slender than that of wheat, which, structurally, it much resembles.

CULTURE, USES, AND DISTRIBUTION

Rye is chiefly a grain of colder latitudes and alpine regions, where wheat fails to thrive. It does fairly well under arid conditions and in poor soil. It is sometimes used as a sand-binder, as a green crop to plow under in sandy and poor soil, and as a catch-crop in orchards. Like most other grains, it is sometimes grown for hay and pasturage. The long, tough straw is one of the best of its class and is used as packing material, as stable bedding, and in strawboard.

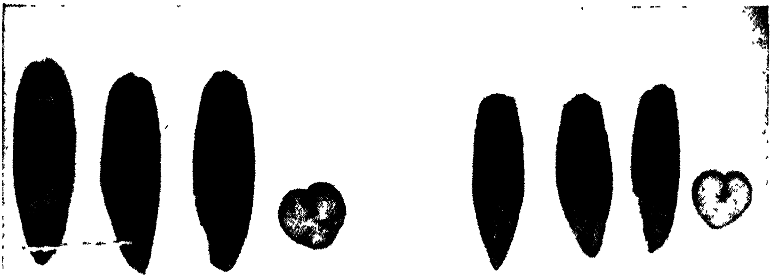

FIG. 214. — Grains of Two Varieties of Rye. (Courtesy Bureau of Plant Industry.)

While rye is a minor grain and a negligible article of human diet in the United States, it is the chief breadstuff of about one third of the inhabitants of Europe, particularly of the poorer classes.

Like wheat, rye possesses gluten and may be made into leavened bread. Its breadstuffs are considerably darker than those of wheat and have a more pronounced, somewhat bitter flavor—factors which prejudice its use in America.

Rye is a well-known source of mash for the distillation of whiskey and alcohol.

ERGOT

Rye is parasitized, particularly in Europe, by Ergot (*Claviceps purpurea*) a fungus (Fig. 215). The hypertrophied grains are poisonous; epidemics of ergotism were common, with many fatalities, in the Middle Ages. By proper methods of cleaning, ergot can be removed from harvested rye and should not be

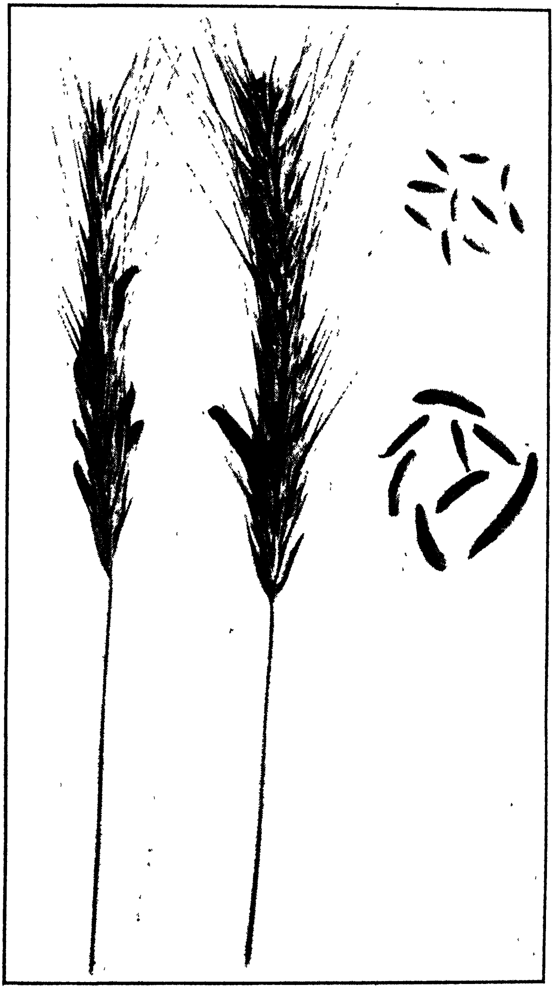

FIG. 215. — Ergot of Rye (*Claviceps purpurea*). The developing ovary is replaced by a black spurlike mycelial growth, the sclerotium, by means of which the fungus survives the winter. (Courtesy Bureau of Plant Industry.)

a source of danger at the present time. Its physiological action is valued in medicine, and ergot is collected in Spain, Germany, and Russia. Ergot is a high-priced drug, but its separation from other refuse in cleaning rye is not commercially feasible in America. Experiments indicate that it may be purposely produced by artificial infection of the growing rye, but commercial attempts to accomplish this seem not to have been made.

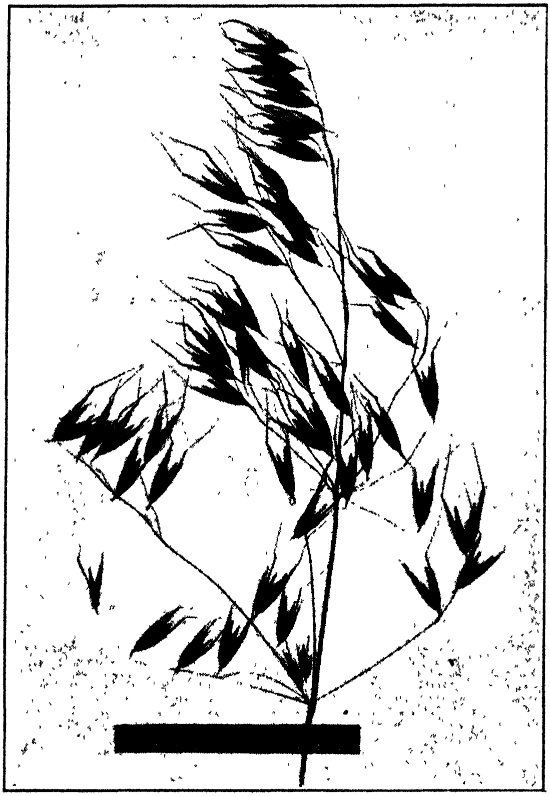

FIG. 216. — The Wild Oat (*Avena fatua*). This is probably the parent of most of the oats in cultivation. The grain is small and worthless. (Courtesy of University of California College of Agriculture.)

WORLD PRODUCTION OF RYE

The principal rye-producing country is Russia, which in some years has produced over 1,000,000,000 bushels and usually equals the output of the rest of the world combined (with the exception of China, for which no statistics are available). Germany ranks second, in pre-war days sometimes exceeding 400,000,000 bushels, much of it harvested in what is now Polish territory. Poland produces somewhat less than present-day Germany. The crop of the United States once (1922) exceeded 103,000,000 bushels, but in more recent years has generally run between 40,000,000 and 60,000,000 bushels. Much of the American crop is exported.

Oats

Oats are from several species or subspecies of large, rankly growing annual grasses of the genus *Avena*. Probably most of the cultivated forms of the grain have been derived from *Avena fatua* (Fig. 216) the European Wild Oat. This often occurs as a weed in cultivated oats and in some localities has become thoroughly naturalized. In rich, slightly alkaline lands of the Central Valley of California, for instance, it dominates the annual herbaceous vegetation of the wet or winter season, covering hundreds of square miles with luxuriant growth, dense

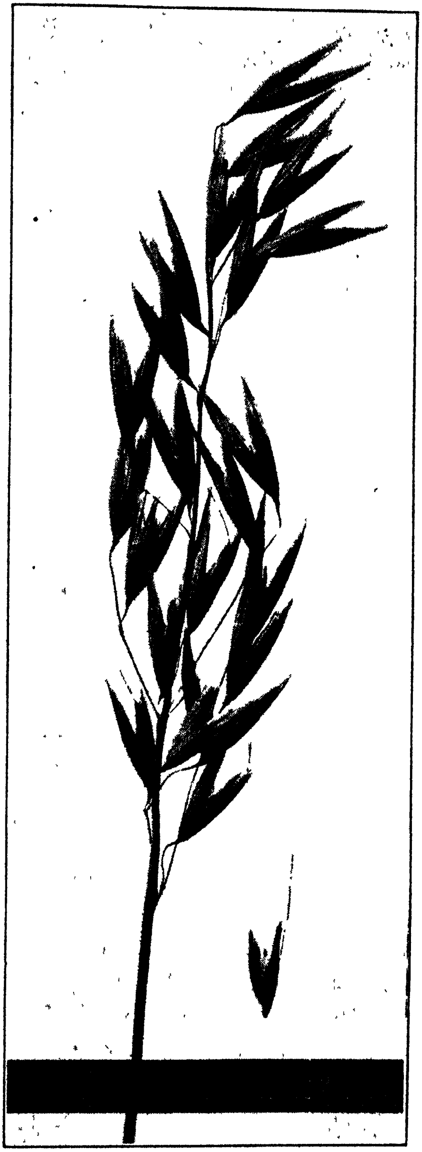

FIG. 217. — The Red Oat (***Avena byzantina***), a Species Commonly Grown in California. It is better adapted to arid regions than is *A. sativa*. (Courtesy of University of California College of Agriculture.)

and valuable for forage and hay, but worthless as grain. Panicle Oats (Fig. 199), including the most common varieties, are generally cited as *Avena sativa,* while Banner or Tartarian Oats are called *A. orientalis.* Mediterranean or Red Oats, including a number of varieties chiefly grown on the Pacific Coast, are derived from *A. byzantina* (Fig. 217). Several other species are recognized but are of little importance in this country.

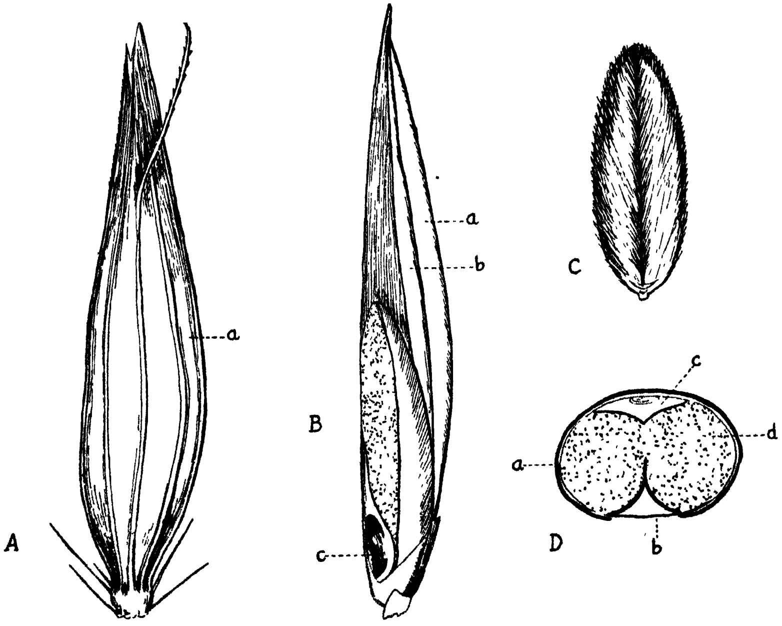

FIG. 218. — The Oat Grain. *A*, grain as threshed, surrounded by lemma and palea, the latter not visible; *B*, the same in section; *C*, the grain or groat, divested of hull (lemma and palea); *D*, the grain in cross-section; *a*, lemma; *b*, palea; *c*, embryo or germ; *d*, endosperm. (Redrawn from a chart by Quaker Oats Co.)

THE OAT PLANT

The oat may reach a height of four feet; it is easily distinguished among the cereals by the bluish-green tint of the foliage and the very characteristic inflorescence. The culms are larger and less stiff, the leaves broader and more numerous, than those of wheat. The leaf-sheath is closed, an unusual thing in grasses. The inflorescence of most varieties is a wide and much-branched panicle; in banner oats it is contracted and one-sided. Spikelets are large and usually long-pedicellate. The prominent, sharply acute glumes surpass the lower floret and sometimes the whole spikelet. Florets are usually three; the second is often sterile and the third almost invariably so. Palea and lemma are prominent, the latter long-awned, or, in some varieties, nearly or quite awnless. The florets open widely but briefly; they are usually self-pollinated.

THE OAT GRAIN

The caryopsis (Fig. 218), unlike that of wheat, remains at maturity firmly invested by a hull of lemma and palea, which constitutes 25 to 35 per cent of the threshed product. As the hull lacks nutritive value and digestibility and adds difficulty to milling, oats with small hull content are desirable. In some varieties —nude or naked oats—the grain drops from the hull on threshing.

The grain proper, or groat, has a hairy pericarp, a double aleurone layer, a starchy endosperm lacking in gluten, and a small embryo.

ENVIRONMENTAL RELATIONS AND CULTURE

Oats thrive best in humid regions of fairly cool summers and are chiefly grown as a summer annual. Culture is widely distributed (Fig. 219); the Northern States of the Corn Belt lead. About 90 per cent of the oat crop is produced in the eastern half of the country, although oats rank second only to wheat in the western portion. Production of oats in the West is increasing.

Water requirement of oats is higher than that of other common cereals, and drought is a common cause of crop failure, particularly in the West. Under favorable conditions, yields and quality of oats in Western States are higher than in any other section. The crop thrives particularly well in irrigated areas in the Rocky Mountain region, but high production costs militate against it here. In the Southern States and on the Pacific Coast, oats may be either fall- or spring-sown.

The average yield of oats per acre in the United States is about thirty bushels.

USES OF OATS

About 70 per cent of the oat crop of the United States is fed to stock, chiefly horses, on producing farms or locally. The 30 per cent entering commerce exceeds in quantity the commercial oat crop of the rest of the world. About half of this 30

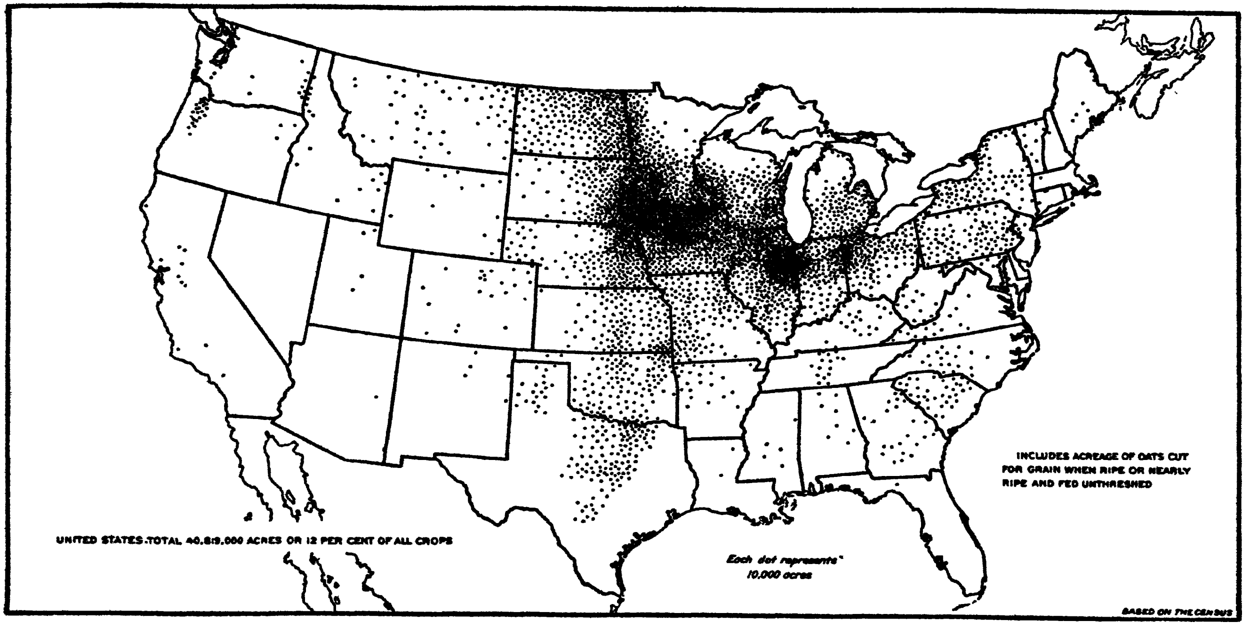
UNITED STATES-TOTAL 40,819,000 ACRES OR 12 PER CENT OF ALL CROPS
INCLUDES ACREAGE OF OATS CUT FOR GRAIN WHEN RIPE OR NEARLY RIPE AND FED UNTHRESHED
Each dot represents 10,000 acres
BASED ON THE CENSUS

FIG. 219. — Acreage of Oats in the United States, 1924. The Oat Belt of the United States consists of a crescent-shaped area extending from Vermont through Illinois and Iowa to North Dakota, bounded on the north by the Great Lakes and on the south by the Corn and Winter-Wheat Region. An arm extends southwestward from this belt across eastern Kansas and Oklahoma to central Texas. Oats prefer a cool, moist climate, and this acreage in the Corn Belt and to the southwest is owing more to the need of feed for horses and of a spring-grain nurse crop for clover than to particularly favorable climate. In the Southern States most of the oats are fall sown; in the North most are sown in the spring. (From United States Department of Agriculture *Yearbook*, 1928.)

per cent, or 15 per cent of the total crop, is also used for stock-feeding. Rolled oats and other breakfast foods consume 4 per cent of the total American crop, and the remaining 11 per cent is sowed or exported.

Oats are among the cereals most frequently grown for pasturage and hay. As roughage for cattle, oat straw is said to be most valuable of all cereal straws. Straw is also much used as bedding. Under unfavorable seasonal conditions, oats intended for grain may be harvested as hay. Often, particularly in the Pacific Coast States, hay oats are grown in mixture with legumes. Oats are frequently used in crop-rotation systems.

As oats, more than any other grain, are fed to horses, it is commonly stated that the rise of farm machinery, the decline of horses on farms, and their virtual elimination from trucking and other urban uses has resulted in a diminished demand for oats. While in two decades horses and mules on United States farms have decreased from about 20,000,000 to 14,000,000, these animals are yet far from extinction. The vast increase of automobiles, trucks, tractors, combines, and the like represent new power sources more than the supplanting of old. Were present power and transportation suddenly and unthinkably to revert to horse-power, the demand for oats and other feedstuffs would of course be vastly greater than it is. It is of interest to note that during the first thirty years of the present century the annual production of oats in the United States was more nearly constant than that of any other grain.

Rolled Oats.—While the proportion of the oat crop which appears on the American breakfast table is not large, oat products are among the favorite cereals of the present day. The traditional oatmeal of Scotland, coarse-ground on stones, is rarely seen in America, its place in our dietary having been more than filled by rolled oats.

Oats from the elevators require a most careful series of cleanings. One large commercial firm states that "almost fifty different machines" are used in this process. After cleaning, the moisture content of the grain is reduced from about 12 per cent to 6 per cent, after which the oats are separated into classes—large oats, slim oats, and stub oats—according to the size and shape. This separation makes for economical grinding.

After grading, the hulls are removed between millstones set at a carefully regulated interval; the lower one is stationary, while the upper revolves at high speed. The oats enter the stones at the center and are thrown between them by centrifugal force.

A series of air-suction cleanings separates the hulls from the groats, which, after final cleaning of dust and pulverized particles, go to the steam-chests. After softening here, they are crushed by heavy rollers into the rolled oats of commerce.

Earlier forms of rolled oats required long cooking to render them palatable. Demand for oat products has been much increased in recent years by the development of a product which requires only three to five minutes for household preparation. "Quick oats" are cut into small pieces and partially cooked before rolling.

WORLD PRODUCTION OF OATS

The United States leads the world in oat production with a crop which, in terms of bushels, exceeds that of wheat. As oats weigh thirty-two pounds per bushel as compared with sixty pounds for wheat and contain 25–35 per cent of indigestible hull, which wheat lacks, the weight and nutrient output of the United States, and even the nutrient yield per acre, are to the advantage of wheat.

Russia, the countries of northern Europe, and Canada, follow the United States in oat production. In no country is the oat as great a commercial crop as wheat. In Europe as in America, it is chiefly used for livestock.

Rice

Rice is the product of various cultivated varieties of *Oryza sativa* (Fig. 220), an annual grass of tropical Asia, Africa, and Australia.

THE RICE PLANT

Rice is a shallow-rooted, rather large grass, some varieties reaching six feet or over. The leaves are long and glabrous, with prominent ligules and hairy auricles. The inflorescence is a panicle whose branches are often paired. The spikelet is laterally compressed, with inconspicuous and scalelike or bristlelike glumes. The lemma is tough, papery, and often awned; the palea similar in structure but somewhat smaller and also sometimes awned. Stamens are six—an unusual number in grasses. The florets are usually self-pollinated. The grain at maturity is invested by lemma and palea. So enclosed, it is called paddy, seed-rice, or rough rice. The grain proper is lustrous and translucent, with a small, inconspicuous embryo and a glassy-white endosperm.

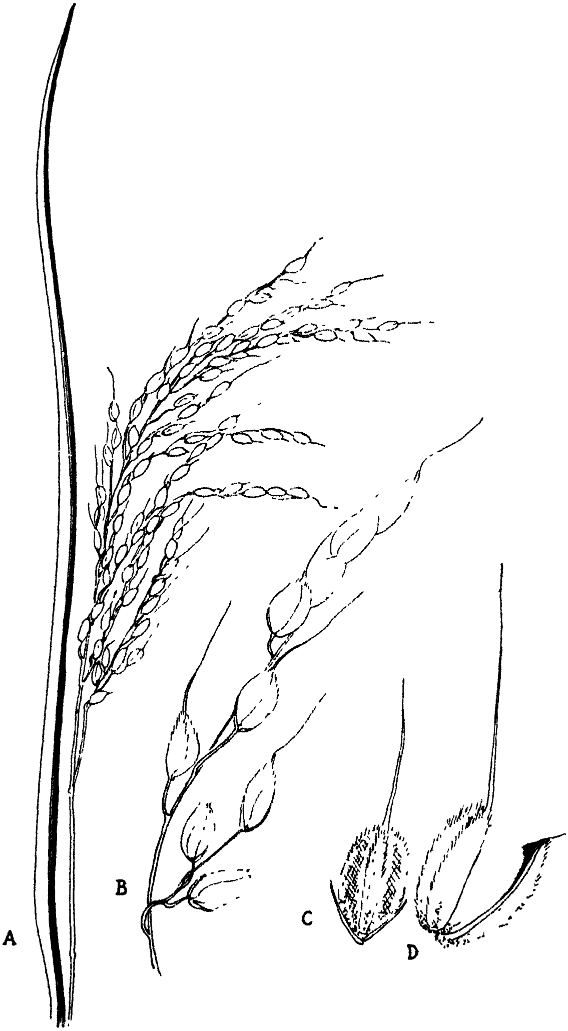

FIG. 220. — Rice (*Oryza sativa*). *A*, portion of leaf and panicle; *B*, portion of panicle; *C*, spikelet, with glumes at base; *D*, spikelet, opened, showing grain; lemma above, palea below. (H. McCarthy.)

ENVIRONMENTAL RELATIONS AND CULTURE

Rice is traditionally a grain of swamps and inundated or irrigated lands. Rice fields are usually flooded during the growth of the plant and drained as the grain ripens. There are a number of upland varieties of rice, which may be cultivated like other cereals, but these are for the most part unimportant in production.

Culture of rice in the Americas began with its introduction to South Carolina in 1694. At the end of the Revolutionary period it was one of the most profitable crops in the South; the recognition of slavery in the Constitution is said to have been a concession to the necessities of labor in the rice swamps. Some rice is still grown in delta land and inland marshes of the South Atlantic coast. At present the great rice-producing regions of the United States are in the prairie country of Louisiana and in southeastern Texas. Rice is also grown in Arkansas and southward in the Mississippi Valley. In the Sacramento Valley of California rice growing has developed mainly since 1912; in quantity this region now compares favorably with all other States save Louisiana.

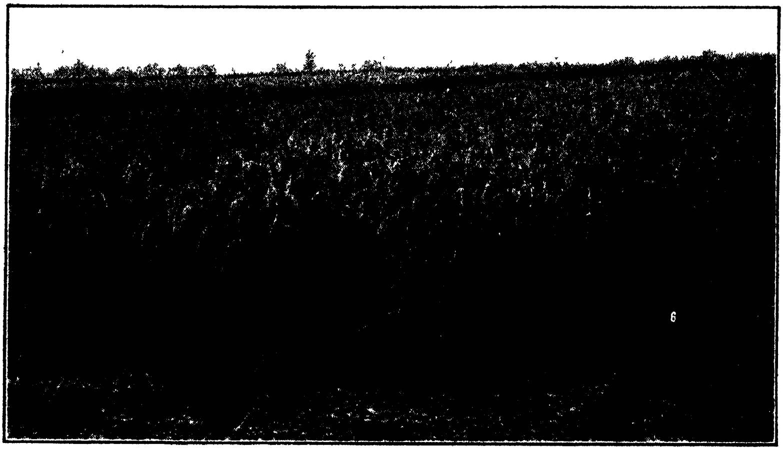

FIG. 221. — Rice in California, Ready for Harvest. At this stage the water which floods the fields earlier in the season has been drawn off for some time. (Courtesy of California Experiment Station.)

Rice farming in Louisiana[1] commenced after the Civil War; its great development dates from the introduction of machinery about 1884. Seed is sown from March to June in level, well-drained fields. All cultural operations—plowing, seeding, harrowing, etc.—are done by power machinery. In three or four weeks from planting the rice is from eight to twelve inches high. It is now flooded from two to four inches deep, and water is kept on till within two weeks from harvest. Flooding serves the double purpose of promoting the rice crop and of drowning out weeds. Costs of flooding are about one fifth of the value of the crop. In this prairie region rice yields forty to fifty bushels per acre.

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[1] Ralph A. Graves, "Louisiana, Land of Perpetual Romance," *National Geographic Magazine,* April, 1930, 393–482.

The rough rice is processed for market in great mills. The grain tips are rubbed off on huge emery wheels and the hulls removed by a machine-brushing process. The product—brown rice—is polished by scouring on leather surfaces till the aleurone layer and oily embryo are removed. A final finishing coats the grain with glucose and talc. While the polishing of rice affords an attractive looking product, it removes valuable constituents from the grain.

FIG. 222. — Threshing Rice in California. (Courtesy California Experiment Station.)

USES OF RICE

Rice is chiefly used for human food in Oriental countries. In the United States it is a minor cereal food. Besides the common household preparations, rice is employed considerably in soup manufacture. It is rarely ground; the rice flour of commerce is from the polishing process. This is an occasional ingredient of prepared mixtures such as pancake flours.

As compared with other cereals, rice is low in proteins; polished rice, lacking the aleurone region, is particularly deficient in this respect, and also in its vitamin content. To supplement rice, the Chinese use soy-beans, which are rich in protein and oil. Continued use of polished rice, insufficiently supplemented by other foodstuffs, causes deficiency diseases.

Rice bran and other by-products are used in stock feeds.

TABLE VIII

Rice, in Terms of Clean Rice: World Production in Millions of Pounds for Years Shown

CROP YEAR	*Estimated world production, exclusive of China*	PRODUCTION IN SELECTED COUNTRIES [1]							
		India	*Japan*	*Indo-China*	*Java and Madura* [2]	*Siam* [3]	*Chosen*	*Philippines*	*United States*
1909–10	107,000	63,869	16,474	.. ..	5,723	3,734	2,343	1,164	572
1920–21	117,000	61,949	19,857	6,284	6,761	5,868	4,639	2,560	1,446
1921–22	127,000	74,240	17,335	7,931	5,964	5,806	4,500	2,681	1,045
1922–23	133,000	75,495	19,067	7,629	7,280	5,954	4,717	2,703	1,150
1923–24	118,000	63,164	17,418	7,206	7,284	6,034	4,767	2,566	937
1924–25	127,000	69,601	17,960	7,801	7,563	6,779	4,153	2,818	895
1925–26	127,000	68,851	18,756	7,951	7,184	5,752	4,641	2,949	924
1926–27	126,000	66,483	17,465	8,255	7,732	7,169	4,807	3,083	1,180
1927–28	127,000	63,244	19,510	8,850	7,951	6,261	5,435	3,082	1,243
1928–29	130,000	72,005	18,945	7,811	7,669	5,325	4,245	3,073	1,207
1929–30	127,000	69,736	18,710	8,095	7,449	5,315	4,304	3,184	1,128
1930–31 [4]	137,000	72,124	21,009	8,004	8,053	6,620	6,026	3,064	1,248
1931–32 [4]	132,000	73,405	17,346	7,773	7,732	5,581	4,987	......	1,278
1932–33 [4]	......	68,667	18,905	......	7,927	.....	5,066	......	1,093

From United States Department of Agriculture *Yearbook*, 1933. Bureau of Agricultural Economics. Both acreage and production figures refer to the year of harvest. Harvests of the Northern Hemisphere countries are combined with those of the Southern Hemisphere which immediately follow; thus, for 1931–32 the crop harvested in the Northern Hemisphere countries in 1931 is combined with the Southern Hemisphere harvest which begins late in 1931 and ends early in 1932. Estimates of world rice production for the period 1900–01 to 1908–09 appear in Agriculture *Yearbook*, 1924, p. 653.

[1] China is an important producing country, but official statistics are not available.

[2] Estimates of the production of rice on nonirrigated land are not available prior to 1916–17. Estimates for the years 1909–10 to 1915–16 as given here are for the production on irrigated land. Estimates for the years 1916–17 to 1931–32 are for the total production.

[3] Estimated figures obtained by multiplying acreage under rice as classified for revenue purposes up to 1912–13, and acreage as reported by the Department of Land and Agriculture from 1912–13 on by an average yield for the years 1920–21 to 1923–24, for which years official estimates have been published of acreage, yield, and total production.

[4] Preliminary.

In Europe, rice is an important source of starch; in this country, it is much outranked by corn.

Sake, the national drink of Japan, is made from fermented rice.

The tough, valuable straw of rice finds application in stock-feeding, for strawboard, and, in the Orient, for a variety of other purposes. Oriental "rice paper," so called because it was formerly supposed to be manufactured from rice, is from the pith of a Formosan tree, *Aralia papyrifera.*

Rice hull waste in Louisiana is used to a limited extent in cellulose manufacture; the bulk of it is burned as refuse.

WORLD PRODUCTION OF RICE

Rice is chiefly a grain of the tropics. The average growing-season temperature of most regions of rice culture is about 77 degrees Fahrenheit. Rice has been the dominant cereal of warmer Asia since prehistoric time. To-day, as in centuries past, it feeds more human beings than any other grain. Failure of the rice crop in India, China, or Japan means national disaster and famine.

The densely populated regions of China are the chief centers of rice production, and no reliable estimates of their tremendous total is available. India follows China in rice culture, and other Oriental regions raise large quantities. An estimate of the world's rice production is shown in Table VIII.

In contrast to the great rice-growing region of Louisiana, where machine labor prevails and great level fields are flooded by huge pumps, Oriental rice is grown in small plots and by laborious hand methods. In some mountainous regions elaborate systems of hand-made terraces are in use.

About 20 per cent of the American rice crop is exported, chiefly to the United Kingdom, Japan, and Germany. Relatively small amounts of cleaned rice are imported from China; because of quarantine regulations, rough or paddy rice can be brought in only from Mexico.

6. Indian Corn, the Grain Sorghums, and Buckwheat

Indian Corn or Maize

THE TERM "CORN"

The words CORN and GRAIN were once practically synonymous, meaning any small particle. Corned beef, for example, was so termed because of its preservation by "corns" of salt. In common English usage, cereals in general were called "corn" long before the discovery of maize. The "corn" of Palestine, as mentioned in the Bible, was, in all probability, wheat. The Corn Laws of English history were restrictive on commerce not only in wheat but in other cereals.

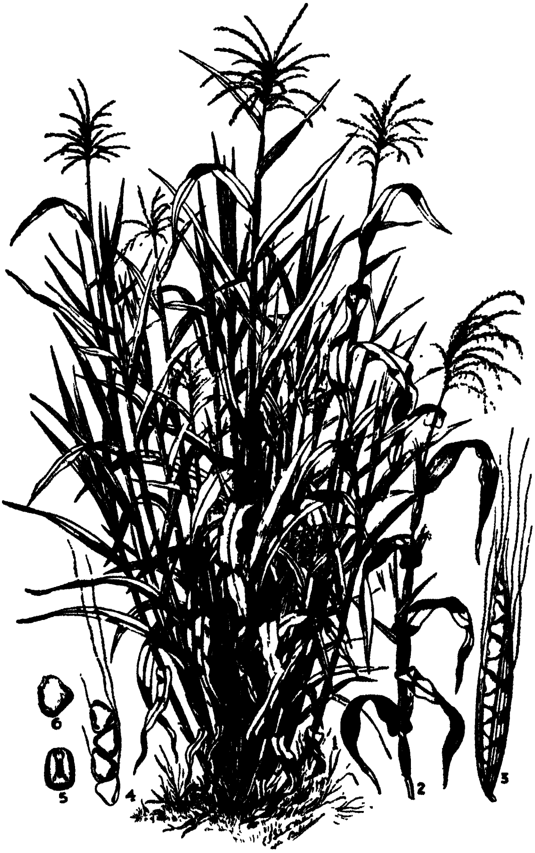

FIG. 223. — Teosinte (*Euchlaena mexicana*), the Probable Ancestor of Maize. (Courtesy Bureau of Plant Industry.)

HISTORY OF INDIAN CORN

The plant botanically known as *Zea Mays* was cultivated on both American continents long before the arrival of white men. Its part in early relations with the aborigines is told in every history of the Colonial period.

Indian corn is not known in the wild state, and its antecedents are uncertain. Its nearest wild relative of the present day is TEOSINTE (*Euchlaena mexicana*), a Mexican plant (Fig. 223), with which it is capable of hybridizing and which may be an ancestral form. Most authorities have considered *Zea* indigenous to the western hemisphere, though it has been claimed, on no very certain evidence, that maize was known in China prior to the sixteenth century. If, as is generally conjectured, the Indian race came from Asia, it is possible that the grain now called Indian corn may have been brought from one mainland to the other at a period long before the dawn of history. Whatever its early connection with Asia, certainly there it never assumed an importance comparable to its place in the primitive economy of the Indian. Corn has been found in prehistoric Peruvian tombs, and Darwin discovered ears of corn embedded on the shores of Peru at eighty-five feet above the present sea-level. In the northern continent, corn was practically the only cereal cultivated by the red men, who appear to have been conversant with all the principal types now grown, as well as with some which have failed to maintain themselves in modern culture.

The Corn Plant

STRUCTURE

Among grasses in temperate-zone cultivation, Indian corn (Fig. 224) is remarkable for its large size, the solid nature of its stems, its monœcious character, and the peculiarities of its pistillate inflorescence—the ear and its kernels. Despite its size, corn is an annual; the length of its season varies considerably with the variety.

The fibrous roots of corn, proceeding from several short nodes at the base of the stem, fill the upper layers of the soil with a profusely branching network. Some, the aerial or prop-roots, proceed from above the ground-line. While corn roots may branch abundantly to a depth of four feet or more, several investigators have indicated that two thirds of the entire underground system is found in the upper four inches of soil—this, with the rapid transpiration of the large leaves, accounts for the susceptibility of corn to drought and to injury from overdeep cultivation.

The stem of the taller dent varieties reaches fifteen feet or more under favorable conditions. Sweet corn and flint corn range from six to ten feet, while some pop corns are less than a yard in height. Branches, known as suckers or stools, are formed from

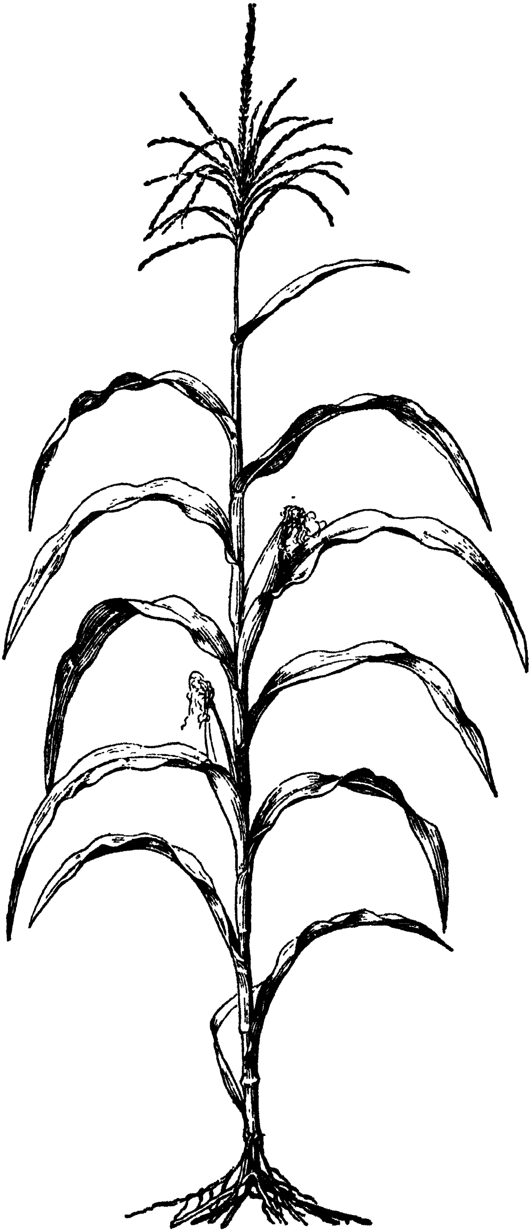

FIG. 224. — Indian Corn (*Zea Mays*). (From Hitchcock, United States Department Agriculture Bulletin 772.)

the lower nodes; these are often removed, as they rarely form ears. In many regions, also, greater yields are obtained when all but one stalk per hill is pulled out while the plants are still small. The pistillate inflorescences, or ears, are borne on short axillary branches.

The structure of the stem, which is generally chosen as the "typical example" of monocotyledonous growth, has been noted very briefly (Fig. 30) in Chapter I.

Leaves are long, ample, of typical grass form; the convergence of many veins toward the center simulates a midrib. The rolling of leaves, so conspicuous in drought, results from turgor changes in certain cells along the upper surface (Fig. 225). When water is abundant, these are distended and the leaf remains flat. In dry weather, the cells shrink and the leaf rolls, thus exposing a smaller evaporating surface to the sun. The lower cuticular surface, moreover, is sufficiently thickened to retard water-loss.

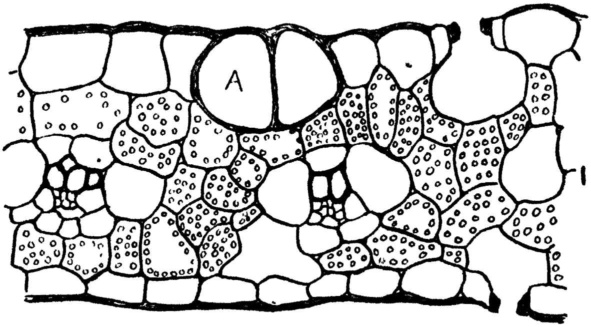

FIG. 225. — Leaf of Indian Corn (*Zea Mays*), in Cross-Section. Through changes in the turgidity of ribbonlike longitudinal groups of modified epidermal cells (*A*), the corn leaf "rolls" in dry weather.

The leaf area of a corn plant is rather considerable. At the Nebraska Experiment Station it has been computed that an average acre of corn produces two acres of leaves—four acres of leaf surface, when both sides are counted.

The staminate spikelets of corn are borne at the extremity of the stalk in a large branched panicle, the tassel. The spikelets, each two-flowered, are arranged in pairs in rows, one sessile and the other pedicellate. At anthesis, great quantities of pollen blow about in air currents.

The ears, or pistillate inflorescences, are borne on short modified branches and clothed with modified leaves, the husks, consisting usually of the sheath alone. The cob, the axis of inflorescence, bears the sessile spikelets in paired rows. Like the staminate, the pistillate spikelet has two florets, the lower being usually abortive. Glumes, and the lemmas and paleas of both flowers form the chaff of the ripened ear. The long silk, though differing decidedly from any pistil-portion of an ordinary grass flower, appears to be stigmatic in function. The style is apparently represented by a short protrusion at the tip of the ovary. Lodicules are missing in the perfect floret.

As a general thing, pollen of the staminate spikelets is liberated before the silks of the same plant become receptive. Corn is thus predisposed to cross-pollination. Shedding of pollen, however, may continue for some days, and self-pollination is by no means uncommon.

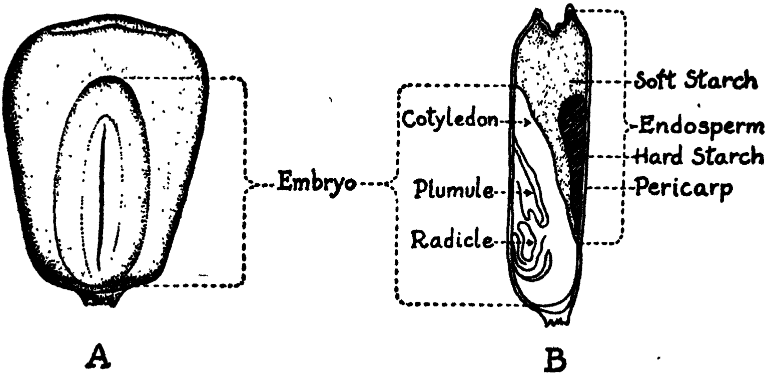

FIG. 226. — Grain of a Dent Corn. *A*, outer view; *B*, median longitudinal section, showing parts of embryo and endosperm surrounded by the fruit wall or pericarp, to which the seed-coats are so closely adherent as to make the whole seem like a single structure. (E. L. Spuller.)

THE CORN GRAIN

The grain of most corn varieties is much larger than the caryopsis of other common cereals. Details of structure vary in the different corn-types; the make-up of a grain of dent corn is shown in Fig. 226. This is broad-wedge-shaped and flattened. In proportion to the whole the embryo is larger than that of the small grains, constituting about 11 per cent, while some 70 per cent of the grain is endosperm. The embryo occupies a groove in the side of the grain toward the tip of the ear.

The aleurone layer is single-celled and in colored corns is pigmented.

Corn endosperm is of two portions, one hard and corneous; the other pulverulent. For these, the terms horny endosperm and starchy or floury endosperm are often employed. As both are in reality chiefly of starch, it is perhaps preferable to refer to them as regions of hard starch and soft starch. Starch granules of the horny region are tightly compacted and angular; those of the soft portion rounded and more loosely arranged. The hard portion is richer in protein than the soft region.

Details of germination of the corn grain have been shown in Fig. 26.

XENIA

It was stated in Chapter I that endosperm in angiosperms results from fusion of a sperm nucleus with a fusion nucleus from the female gametophyte. The endosperm is therefore a zygote and evidences the transmission of such characters as it exhibits in Mendelian manner. In most plants, endosperm is so inconspicuous, that it shows little visible variation. In corn, however, it is bulky and conspicuous, comprising all the portion of the kernel that is visible when on the ear. It shows Mendelian variation in many characters, such as form, starchiness, and color. Yellow endosperm, for example, is dominant over white. Purple or red, which usually resides in the aleurone layer, is dominant over colorless aleurone. If a cross occurs between a dent and a sweet corn, the kernels are starchy, like those of the dent parent. This visible appearance in the seed of dominant characters from the male is known as xenia (Fig. 227).

SELF-FERTILIZATION IN CORN

Early corn breeders usually selected propagating stock on the mass-

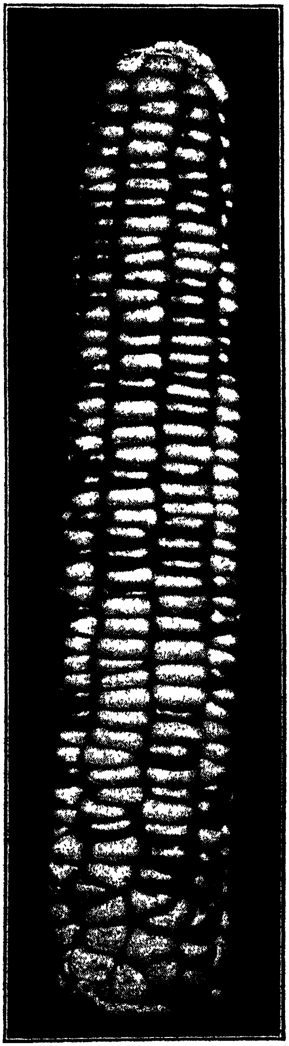

FIG. 227. — Xenia. Some of the ovules of this ear of white flint corn were fertilized by pollen from yellow flint, and the endosperm-character resulting shown in the darker grains. (Courtesy of University of Wisconsin College of Agriculture.)

selection principle, on basis of appearance, weight of ears and kernels, and with some attention to yield of the stalks from which the ears were taken. Inasmuch as fertilization in wind-pollinated plants is purely a matter of propinquity and chance, the kernels of a single ear may have a wide variety of staminate parents. some desirable, some not. Evidence of this mixed parentage may appear at once in xenia and in variations of stature,

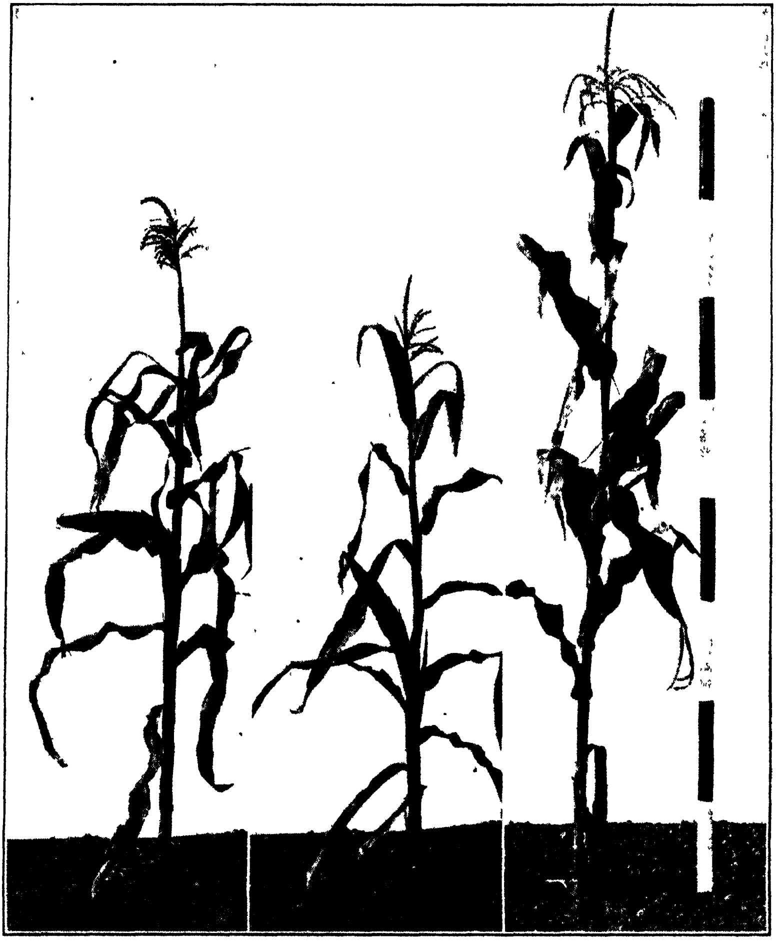

FIG. 228. — Pure Line Breeding and Combination in Corn. On the left are two pure-line extractives of a dent corn; the plant on the right is from the first generation from this parentage. All were photographed on the same scale. (Courtesy of United States Department of Agriculture and University of Illinois; Bulletin 255 of Illinois Agriculture Experiment Station.)

yield, and crop upon the development of the embryo. When seeding-stock of known ancestry is desired, it is therefore necessary to resort to artificial pollination with precaution against the advent of undesired pollen.

Self-fertilization in corn brings about segregation of dominant and recessive characters; continuance for a series of years establishes pure lines whose selfed progeny breed true. It also results in much diminution in plant vigor and in yield. By judicious cross-breeding of pure lines, however, and recombination of desirable characters, it is possible to establish high-yielding corn strains of excellent quality (Fig. 228). This process is now in common use by corn breeders.

The Principal Types of Corn

All types of corn are generally considered varieties or subdivisions of a single species, *Zea Mays*. Four groups, DENT corn, FLINT corn, SWEET corn, and POP corn include nearly all varieties at present grown. Of these, dent corn (Fig. 229) is supreme throughout the Corn Belt and elsewhere save toward the northern and alpine limits of the corn-growing region. Most dent varieties are large, rankly growing plants, producing immense yields both of fodder or forage and shelled corn. The principal commercial varieties require a rather long season to reach maturity. Toward the northern limits of corn cultivation, where the ears of dents do not ripen, these varieties are still extensively grown for forage, fodder, and ensilage.

The kernels of dent corn (Fig. 226) are large, wedge-shaped, and many-rowed. The soft starch extends to the top of the kernel; it is surrounded below by hard starch. The "dent" results from shrinkage of the starchy mass as it ripens.

Dent corns are both yellow and white. Some portions of the country, particularly the South, prefer a white corn and meal; while others, such as New England, demand yellow. Recent researches indicate that the vitamin content of yellow corn is considerably above that of white varieties; that the latter, indeed, is quite deficient in these essentials of nutrition and may therefore give rise to serious ailments among consumers whose mainstay it is.

Flint corn (Fig. 230) is a smaller grain, usually of broader proportions, few-rowed, and borne on a slender cob. The soft starch is covered above as well as on the sides with horny material; and the grain is, as the name indicates, very hard. Flint varieties are found in New England, Canada, and elsewhere where the growing season is short; the comparatively small stature and low yield of the slender ears tends to limit this corn, in North America, to regions where dents do not mature. Flint is also the chief corn of Argentina.

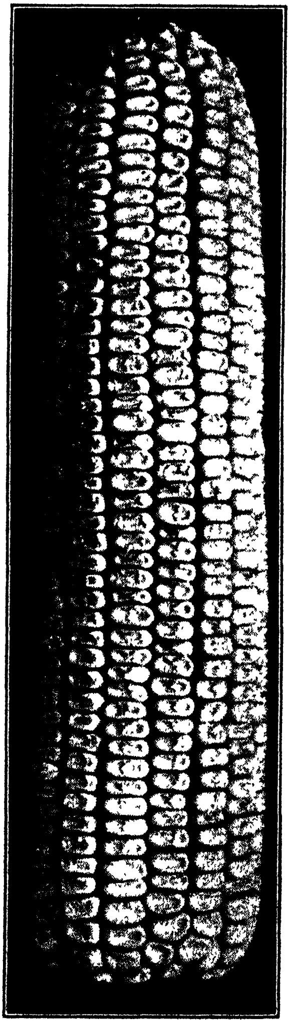

FIG. 229. — An Ear of Dent Corn. (Courtesy Bureau of Plant Industry.)

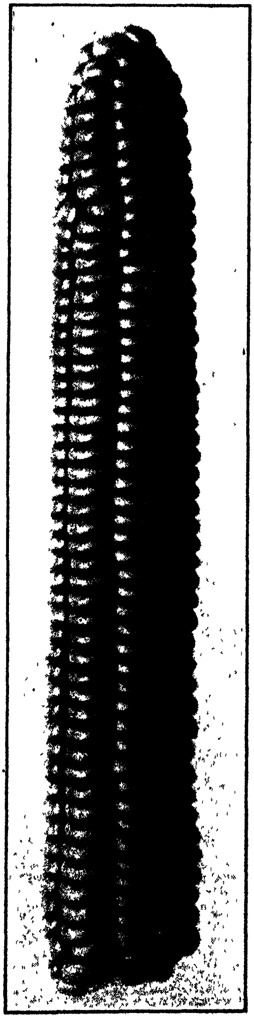

FIG. 230. — An Ear of Flint Corn. (Courtesy of Bureau of Plant Industry.)

Most flint corns are bright yellow; nearly colorless varieties are known, and red and mottled ears often occur.

Pop corns (Fig. 231) are small grains; some varieties resemble miniature flints, but those most commonly seen are sharply pointed at the top and pale yellow or white in color. Pop corns are flinty, possessing much hard starch and enveloped in a very tough pericarp. Popping depends upon starch and water-content; it is, in fact, a miniature boiler-explosion in which the confined steam suddenly ruptures starch grains and cellular structure, with the familiar result. Extremely dry pop corn merely cracks.

Pop corn is rather widely grown on a household scale. The commercial raising of pop corn is very largely localized in one or two counties in western Iowa.

Sweet corn is high in content of sugar and soluble carbohydrates and lower in starch than other common types. The grains are tender and milky when unripe and hard, horny, translucent and wrinkled when dry. As sweet corn is wholly used in the unripe condition, it is valued according to flavor and freedom from hard endosperm and tough hull or pericarp. Most sweet corns are white; a few yellow ones, such as Golden Bantam (Fig. 232) are in high favor.

Sweet corn thrives best in the cooler portions of the corn-raising territory where the frost-free season ranges between 85 and 120 days. Excessive heat, and particularly drought, is most injurious. The principal development of the American sweet corn industry is for canning, and is in the States of Illinois, Minnesota, Wisconsin, Iowa, Maine, and several others. Sweet corn is ranked among the three most important canned vegetable commodities;[1] the maximum pack was 24,000,000 cases in 1925, while the average for 1917–1928, inclusive, was about 14,000,000 cases. Husks and the stalks and leaves (stover) are valuable by-products used locally for livestock feeding.

Commerce in sweet corn on the ear is somewhat restricted by the fact that it soon becomes tough after picking, and more considerably by quarantines designed to curb the spread of the European corn-borer, a destructive insect rather recently introduced into the United States, which is disastrous not only to corn but to a large number of other crops.

Several other corn subspecies are botanical curiosities. Soft corn has no hard starch. In starchy sweet corn, a starchy region forms the lower portion of the grain. In pod corn the glumes, lemma, and palea are larger than those of other types and

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[1] J. H. Beattie, "Growing Sweet Corn for the Cannery," U.S.D.A. *Farmers' Bulletin No. 1634* (1930).

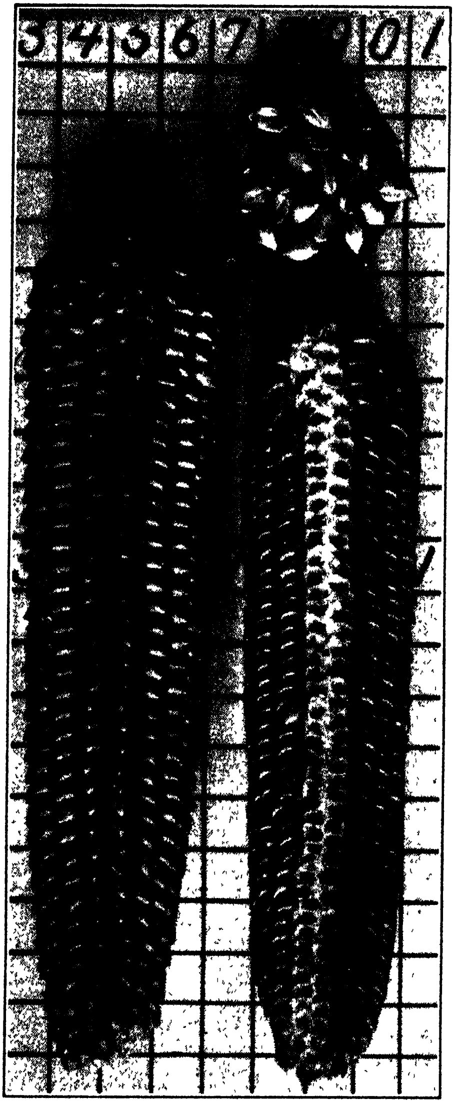

FIG. 231. — White Rice, the Most Common Variety of Pop Corn. (Courtesy of Bureau of Plant Industry.)

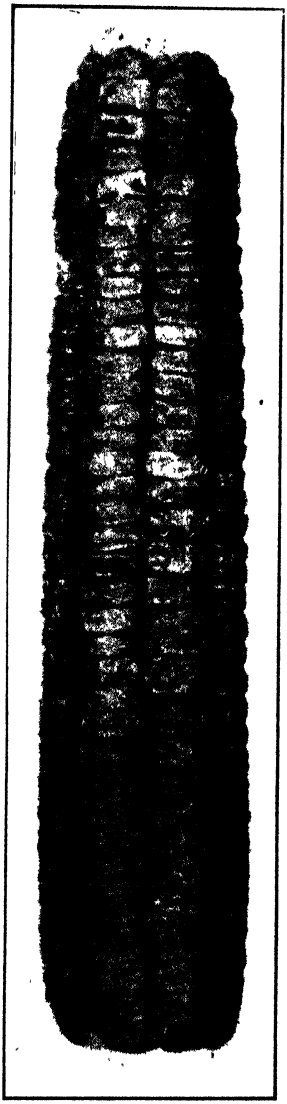

FIG. 232. — Golden Bantam, a Popular Early Yellow Variety of Sweet Corn. (Courtesy Bureau of Plant Industry.)

enclose the grain at maturity. These last corn types were cultivated by Indians of the southwest and of South America but have nothing to recommend them to present-day use.

The Corn Belt

No other major American farm crop has a wider range than corn. It is grown in every State and on three fourths of the farms of the Union. More than half the annual crop, however, is in the so-called CORN BELT (Figs. 197 and 233), a rich prairie region extending from Ohio to southeastern South Dakota and southward through Kansas. It includes part of all of Ohio, Indiana, Illinois, Iowa, Nebraska, Kansas, and Missouri. This band of States has been termed the world's greatest food-producing area. Farms are large and highly mechanized. The soil is rich. Rainfall and climatic conditions, while rather uncertain, are at their ideal best for corn production and also for the raising of other grains. The Corn Belt includes the southern extremity of the spring-wheat region and a considerable amount of the winter wheat country. Hay, oats, and barley are important supplementary crops. Yields of corn in the Corn Belt average about thirty-three bushels per acre; for the United States as a whole, about twenty-eight bushels.

Plant products are not the only crops of the Corn Belt. On its farms are raised over 65 per cent of American packing-house products including over 50 per cent of the hogs and 36.6 per cent of cattle other than milk cows. Forty per cent of both poultry and eggs come from the Corn Belt. It is reckoned that ten to twelve pounds of corn make one pound of beef or two pounds of pork. That the great American corn crop goes to market so largely on the hoof represents, to vegetarians at least, a great waste of energy, but one which seems likely to continue for some time.

Chicago is the great outlet for commercial corn, handling about one third of the crop which reaches the ten primary markets of the Corn Belt.

Uses of Corn

It has been estimated that 85 per cent of the American corn crop is consumed on the farms on which it is raised. Forty-one per cent is fed to hogs, 20 per cent to horses and mules, 17 per cent to cattle and sheep, 4 per cent to poultry, and 3 per cent is used for human food. As to the commercial crop, 6 per

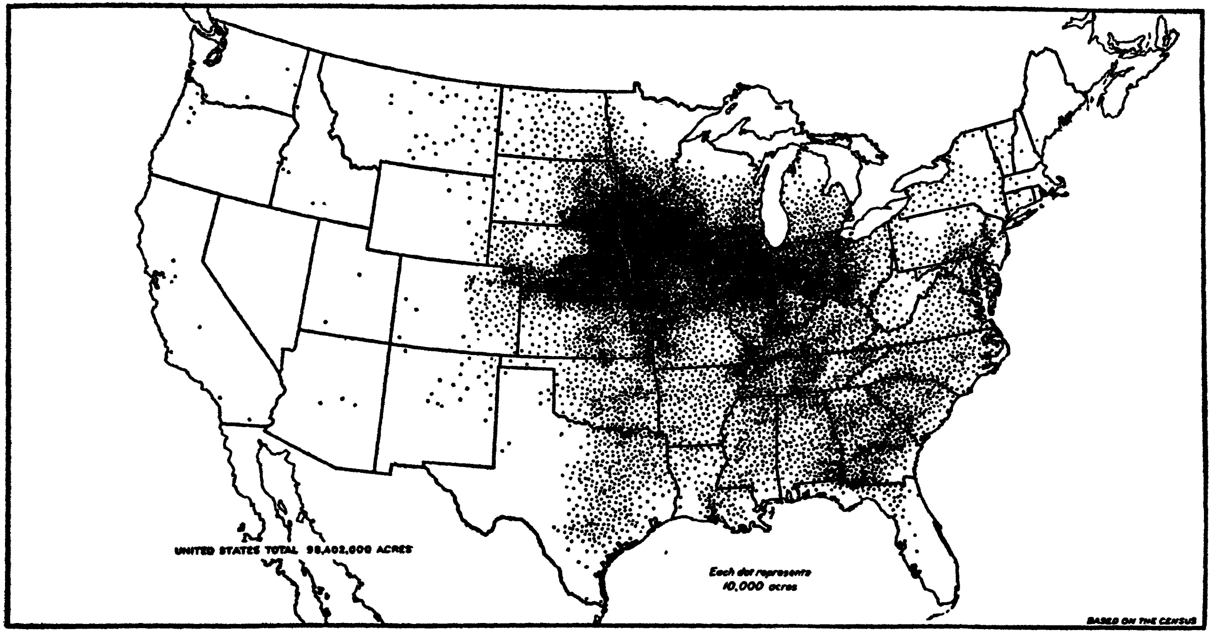
UNITED STATES TOTAL 98,402,000 ACRES
Each dot represents 10,000 acres
BASED ON THE CENSUS

FIG. 233. — Corn Acreage of the United States, 1924. About 60 per cent of the corn of the world is produced in the United States, nearly all east of the line of eight inches mean summer rainfall and south of the line of 66° mean summer temperature. Nearly 90 per cent of the corn production in the United States is in the Corn Belt, the Corn and Winter-Wheat Region, and in the Cotton Belt. In the Corn Belt production exceeds 3,000 bushels per square mile and in some counties rises to 5,000 bushels. About half of the corn produced in the United States and nearly one third of the world's crop is grown in the Corn Belt. (From United States Department of Agriculture *Yearbook*, 1928.)

cent of the nation's output is fed to stock; 4 per cent is made into grits, meal, flour, breakfast foods, and other preparations for human use; 4 per cent goes into a variety of other uses, and 1 per cent is exported.

Corn is lacking in gluten. Alone, it is unfitted for light breadmaking; for most oven purposes the meal or flour is mixed with rye or wheat. "Rye 'n' Injun" bread was a Colonial standby. To-day, human consumption of corn is chiefly in the South. Particularly in the more inaccessible regions of the Southern Appalachians and the Ozarks, corn is the main crop and almost the sole vegetable food. Comparative ease of marketing in liquid form accounts for certain governmental difficulties in those roadless and rather lawless regions. Corn has long been among the mainstays of the distilling industries, legal and illegal.

Flint corn, as cracked corn (coarsely broken grains) is particularly valued for poultry and pigeons.

CORN FOODS

Among the principal products of the corn for human consumption are grits, hominy, corn meal, corn flakes, corn starch, and corn oil. A primitive corn food, borrowed from the Indians by early settlers, was hulled corn; in this the whole kernel was treated with lye or ashes to remove the tough pericarp, and then cooked soft. In modern milling of corn, the shelled grain is carefully cleaned by machinery and then "tempered" with steam and water so that pericarp and embryo may readily be removed. The corn is then broken coarsely, freeing germ and hull, after which it is further ground on corrugated rollers and cleaned and resifted into various grades. Grits are rather coarse particles, largely made of white corn and used in the South. Meals are more finely granular; the product is rarely reduced, like wheat or rye, to fine flour.

The popularity of corn as a breakfast food has been greatly enhanced by the introduction of corn flakes, under a variety of trade names.

In the manufacture of corn flakes the selected and cleaned grain is steamed and the hull and germ removed. The remaining endosperm is sweetened and flavored, and then cooked under steam pressure for some hours. It is then partially dried and flaked by means of rollers which exert a pressure of many tons. The flakes are carried on belts to great drum-ovens where, constantly stirred, they are highly but briefly heated—toasted. After cooling, the flakes are packed by machinery into paraffined bags and boxed. As they are very hygroscopic, it is essential that moisture be excluded during storage.

THE CORN PRODUCTS INDUSTRY

Corn is the source of a variety of manufactured products, such as corn starch, glucose and its derivatives, dextrin products, and corn oil. Corn starch, prepared by a rather complicated process, is the basis of manufacture of all these save corn oil.

Corn for starch manufacture is first soaked in warm, slightly acidified water and then ground. The starch is separated from other grain debris by processes of sifting and gravitational settling. The dried starch is used for laundry purposes, paste manufacture, and in desserts and other culinary preparations. It is almost tasteless, whereas potato starch, its most important commercial rival, is rather unpalatable to most persons. While potato starch is largely employed in Europe, in this country corn is usually a cheaper source, even of the starches which are not designed for human consumption.

The glucose or corn syrup of commerce is a thick syrupy liquid prepared by more or less complete hydrolysis of starch by acid, with subsequent neutralization. It contains considerable dextrin. Glucose has about half the sweetness of cane sugar. It lacks distinctive flavor and is extensively used for table blends with cane and maple syrup and in the making of jams, jellies, marmalades, and preserves.

A more highly purified glucose, known as corn sugar, has recently appeared upon the market. It resembles cane sugar in appearance and is about three fourths as sweet. For many purposes it is said to be interchangeable with cane sugar, at least as a partial replacement in ice creams and preserves. It is also reputed of special value in bread-making, fermenting rapidly and improving the texture and character of the loaf. During the period of prohibition, corn sugar was accused of entering largely into illegal fermented products.

Dextrins and British gums are made by incomplete hydrolysis of starch; they are employed as adhesives on envelopes, gummed labels, and in mucilages. They are also used in various processes for stiffening fabrics and preparing them for dyeing.

Corn oil is a product of the embryo. It is employed as a culinary oil and in the making of soaps and paints. By chemical processes it may be converted into a rubbery mass useful for erasers and various other purposes. The press-cake from oil manufacture and the protein-bearing residues of starch manufacture are fed to stock.

CORN BY-PRODUCTS

Corn stalks and husks are among the principal American farm wastes. Stalks are used to some extent for fodder, but if dried are rather tough and unpalatable. Green corn stalks and other undried plant products are preserved on farms as ensilage. The silo (Fig. 234) in which ensilage is stored, is a huge, generally cylindrical tank, of wooden staves, tiles, or other material, in which the chopped fresh material is allowed to undergo a partial fermentation. Ensilage is considered a most valuable feed, but corn stalks on which the ears have ripened and dried are too dry for this use.

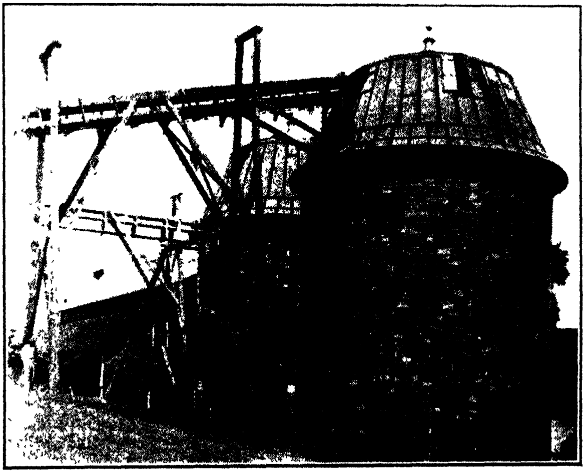

FIG. 234. — A Silo. (Courtesy Bureau of Plant Industry.)

Corn stalks have been repeatedly suggested as a paper source. The large pith and small fiber content has been considered objectionable for this purpose; recent investigations, however, are said to have developed a feasible process for pulping corn stalks.

Corn-cobs are sometimes burned as fuel; they are traditionally used, but at the present time little employed, for smoking pork products. Cobs of one particularly large variety are used for corn-cob pipes. Corn husks, in an earlier period, filled many a colonial mattress, and are still employed in some of the cheaper grades of mattresses and upholstery.

Chemical research has developed a large variety of potential corn-waste products, but thus far these have found little industrial development.

TABLE IX

CORN: WORLD PRODUCTION IN MILLIONS OF BUSHELS FOR YEARS SHOWN

CROP	*Estimated world production, excluding Russia*	*Estimated European production, excluding Russia*	SELECTED COUNTRIES						
			United States	*Argentina*	*Rumania*	*Yugoslavia*	*Italy*	*Brazil*	*Russia* [1]
1900–1901	3,593	445	2,505	99	85	18	88	.....	34
1919–20	4,075	454	2,649	259	[2] 141	....	86	197	....
1920–21	4,530	519	3,049	230	182	[2] 101	89	186	46
1921–22	4,154	393	2,912	176	111	74	92	181	46
1922–23	4,025	424	2,689	176	120	90	77	202	81
1923–24	4,332	469	2,860	277	153	85	89	180	67
1924–25	3,874	589	2,305	186	155	149	106	162	91
1925–26	4,517	626	2,853	322	164	149	110	162	172
1926–27	4,375	653	2,575	321	230	134	118	164	131
1927–28	4,241	485	2,678	312	139	83	87	133	118
1928–29	4,224	384	2,715	252	109	72	65	194	130
1929–30	4,317	705	2,535	281	251	163	100	174	119
1930–31	3,904	611	2,060	420	178	136	118	200	105
1931–32	4,307	629	2,567	285	239	126	77	......	....
1932–33 [3]	....	748	2,908	......	224	178	119	.....	....

From United States Department of Agriculture *Yearbook*, 1933. Bureau of Agricultural Economics. Official sources and International Institute of Agriculture. Both acreage and production figures refer to the year of harvest. Harvests of the Northern Hemisphere countries are combined with those of the Southern Hemisphere which immediately follow; thus for 1931–32 the crop harvested in Northern Hemisphere countries in 1931 is combined with the Southern Hemisphere harvest which takes place early in 1932.

[1] Includes all Russian territory reporting for the years shown.

[2] Production in present boundaries beginning this year, therefore not comparable with earlier years.

[3] Preliminary.

World Production of Corn

Maize has always been preëminently a grain of the western hemisphere. The United States furnishes about half the world's supply (Table IX). Argentina is next with a crop considerably smaller, yet important in the rather limited world market, in which this South American republic is our chief competitor. Argentine corn is of the flint type; North American imports of it are used in feeding fowls.

Corn production in Europe is not large. European corn is chiefly consumed in the producing countries—Russia, Italy, Roumania, Spain, and Portugal—where it is baked, with rye, into "black bread." Corn is also raised in Africa by natives. There it is called "mealies."

The Grain Sorghums

The sorghums, which are generally cited as varieties of *Andropogon Sorghum*, are probably cultivated annual derivatives of *A. halepensis*, which, under the name of Johnson Grass, is a well-known and dreaded weed in the southern United States and in California.

The sorghums are shallow-rooted annuals with solid culms three to fifteen feet in height. Save for differences of inflorescence and a more branching habit, the plants resemble those of *Zea*. They sucker more freely from the base and also branch from the higher portion of the culms. The inflorescence (Fig. 235) is usually a compact panicle or head; in the broom corn group (Fig. 236) the branches of the rachis are slender and greatly elongated. Spikelets are paired, or more rarely in threes. One is sessile and fertile; the others pedicellate and staminate. Either close-pollination or cross-pollination may occur. Grains of different varieties differ somewhat in shape.

Sorghums are tropical plants, tolerant of high temperatures but lacking in hardiness. They are among the most drought-resistant of grain crops and are important in the semi-arid west. Texas is the principal American producer of grain sorghums, and Oklahoma leads in broom corn.

Many varieties of sorghums exist, some of which are known by foreign vernacular names. The saccharine sorghums, collectively known as SORGO, possess juicy pith, rich in sugars, which is used for syrup manufacture (see Chapter X). These kinds are chiefly grown in the Southern States. Of the grain sorghums (grown for grain, forage, and ensilage) Kafir, Shallu, Kaoliang, and White Milo (often referred to as Kafir Corn and Milo Maize) form erect cylindrical panicles whose grains are somewhat obovate. Durra, Feterita, and Yellow Milo possess pendant panicles and flattened seeds. In Asia these grain sorghums are much more widely used than in the United States. In the broom

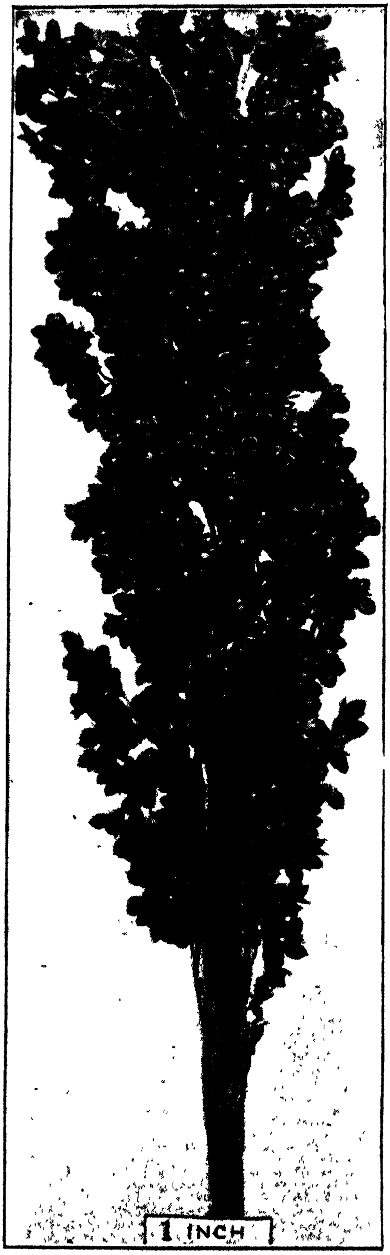

Fig. 235. — A Panicle of a Sorghum. (Courtesy of Bureau of Plant Industry)

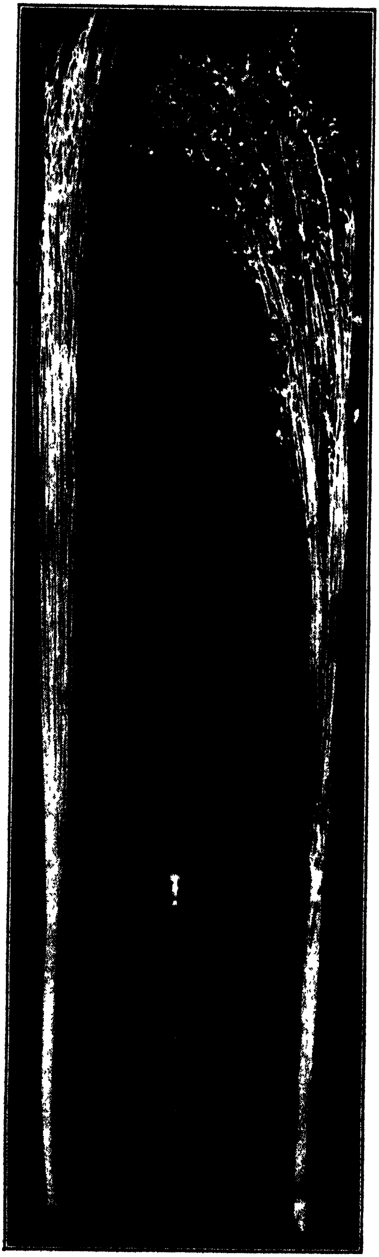

Fig. 236. —Panicles of Broom Corn, Threshed and Unthreshed. (Courtesy of Bureau of Plant Industry.)

corn group the panicles are loose and long-branched; the slender branches are the familiar straw of brooms and whisk-brooms.

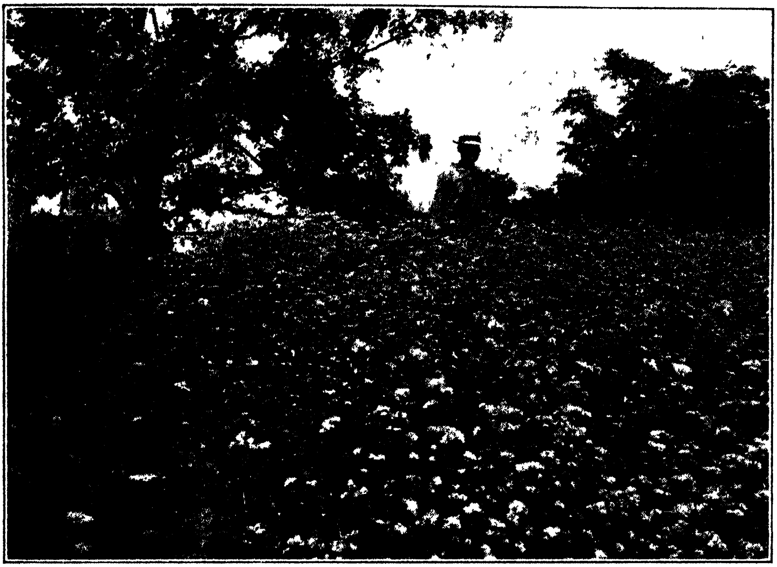

FIG. 237. — A Field of Buckwheat in Pennsylvania. (Courtesy of Bureau of Plant Industry.)

Buckwheat

Buckwheat is peculiar in being the only plant outside the *Gramineæ* which has any important use as a "cereal" in North America. The plant, *Fagopyrum esculentum* (Fig. 237) is an Asiatic member of the Polygonaceæ. The pointed triangular achene (Fig. 238) is rich in starch and protein.

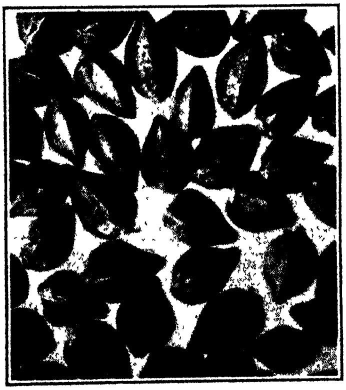

FIG. 238. — Buckwheat. (Courtesy of Bureau of Plant Industry.)

Buckwheat is a short-season annual, grown chiefly in regions of cool and rather moist summers. It does fairly well on poorly drained land and in acid soils. New York and Pennsylvania produce more than half the buckwheat crop of the United States.

The buckwheat plant is used

for green manuring and as a cover or catch-crop in orchards. The grain is fed to stock and poultry. Buckwheat flour is employed in pancake mixtures. Buckwheat is more important in northern Europe than in the United States. In 1927, 84 per cent of our exports went to the Netherlands.

Buckwheat is one of the principal honey-crops of its region.

7. HAY AND FORAGE

Herbage Crops and Their Utilization

HAY is composed of the above-ground parts of grasses, legumes, and occasionally other plants, dried for use as stock feed. The term FORAGE refers to such plants consumed in the green state, or at least without harvesting, in open land range and pasture. Some idea of the significance of stock-feeding in the American agricultural industry can be gained from Fig. 239. In the years since this diagram was made some increase of tillage has taken place, but in broad outlines the picture remains the same. Livestock consume about three fourths of the product of the improved land of the United States and practically all that of the product of unimproved pastures and grazing lands—within and without farms—which in any direct way contribute to human utilities. Although the great herds of bison are gone and deer and other large herbivores are reduced to fractions of their former numbers, much herbage is still eaten by wild animals and large quantities are consumed by insects. That which dies and decays is not "wasted," but, as humus, remains, perhaps, for some future use which the anthropocentric mind may conceive as "utility."

Plants used as feedstuff are usually of greatest value when consumed fresh, but this can scarcely be done under winter conditions. Horses and other feeding animals, moreover, are often kept remote from grazing lands. The cereal grains are of course the most concentrated plant feedstuffs, and the use of ensilage has already been referred to.

The simple air-drying of grasses and leguminous plants long antedated the silo, and the process is still continued on a large scale. Moreover, the slender culms and leaves of timothy and other forage grasses and the herbage of clovers and other small legumes are much less suitable for ensilage than the coarser substance of corn stalks and the cereal straws.

In the earlier days of American agriculture grasses were almost the sole source of hay. The introduction of clovers, alfalfa, and other legumes of high nitrogenous content was a vastly important step; and the increase of dairying and scientific studies

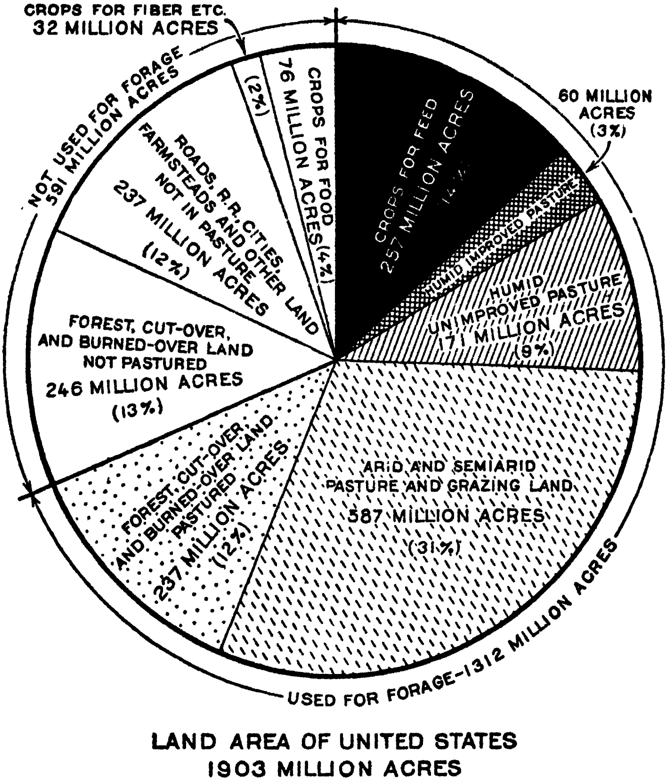

FIG. 239. — Land Used for Forage and Other Purposes in the United States. About 69 per cent of the total land area of the United States was used in 1919 for the production of forage. Some of this, for instance the forest land that was pastured, contributed other products than forage. The above statement merely indicates the immensity of the land area required for the support of the nation's livestock. The 257,000,000 acres producing crops for feed yielded slightly more sustenance than the 1,055,000,000 acres used for pasture. More than half of this pasture is arid western range and nearly a fourth more is forest and cut-over land which, in general, has a low carrying capacity. (From United States Department of Agriculture *Yearbook*, 1923.)

of animal feeding, as well as demonstrated fertility values, have increased the use of hay-producing legumes and particularly of alfalfa. Feeding requirements of draught animals are somewhat different from those of dairy cattle, and these from those of beef and other meat-producing stock. Grass hay, or grass mixed with clover, has been highly favored for horses. Motorization of road transport, increasing use of tractors and other power machinery on farms, and the virtual elimination of horses in cities, have brought about important changes in the production, use, and movement of hay.

The chief hay-growing regions are shown in Fig. 240. Much wild hay, consisting chiefly of grasses, is obtained from salt marshes, uncultivated plains and prairies, etc., in the northern United States and Canada. Both hay grasses and the clovers find their best natural conditions in this region. Here, indeed, grasses are the most prevalent weeds, quickly taking over abandoned fields and farm-lands by natural seeding, whereas in the Southern States fallow land is overrun with composites and other worthless vegetation, and it is difficult to maintain a stand of hay of forage value. The great cereal States of the Mississippi Valley are natural hay-producing areas, but, here, as has been noted, the grains predominate. Under western conditions and on irrigated land, alfalfa is the hay crop *par excellence*; this legume is also much grown in the east. The principal legumes used for hay and forage are noted in Chapter XII.

About three fourths of the tame hay of this country is grown in the Northeastern States. In 1927, 30 per cent of tame hay was alfalfa, 26 per cent clover and grass, 14 per cent clover, 12 per cent grass, 9 per cent millet, 5 per cent annual legumes, 4 per cent cereal grains cut green. About four fifths of the annual crop is consumed on farms where grown. Relatively small quantities of hay are imported into the eastern United States from Ontario and Quebec.

The Hay Grasses

About 1,500 species of grasses occur in the United States. About sixty of these are cultivated; many of them have been introduced from other countries. About sixty are troublesome weeds; these are mostly European. Some grasses, of course, are native both to this and certain other continents. Many of the native species are valuable in pastures and range lands and figure to some extent in hay production, but cultivated hay is chiefly from a number of introduced or cosmopolitan species, of which Timothy (*Phleum pratense*), Millet, a term embracing a number of annual grasses; Kentucky Blue-Grass (*Poa pratensis*); Redtop (*Agrostis alba*); Orchard Grass (*Dactylis glomerata*). Meadow Fescue and other fescues (*Festuca* spp.); and Rye-grass (*Lolium*

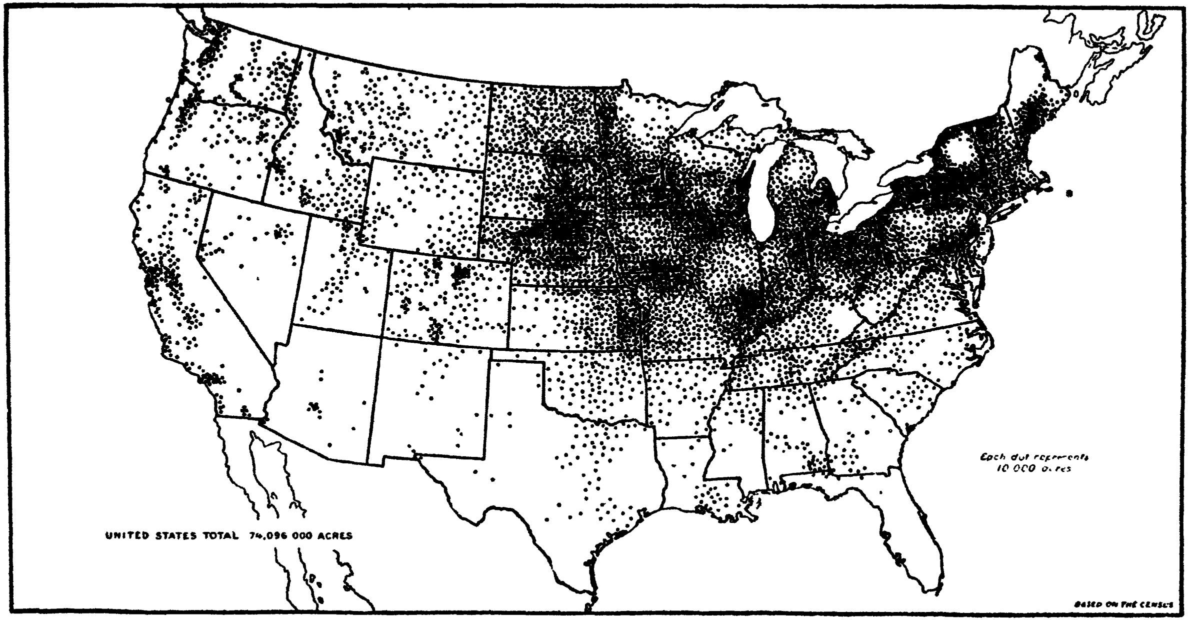

FIG. 240.—Hay Acreage of the United States, 1924. This map includes both wild and tame grasses and legumes cut for hay, including cowpeas, soy-beans, and peanuts cut for hay, but not corn and the sorghums cut for silage or fodder, nor root crops used for forage. The hay crop is concentrated largely in the Hay and Dairy Region and around the margin of the Corn Belt. The greatest State acreage and production is found in New York; next come Wisconsin, Minnesota, Iowa, and Nebraska. Relative to acreage in crops, hay is most important in the Rocky Mountain region, where it occupies over half of the crop land. (From United States Department of Agriculture *Yearbook*, 1928.)

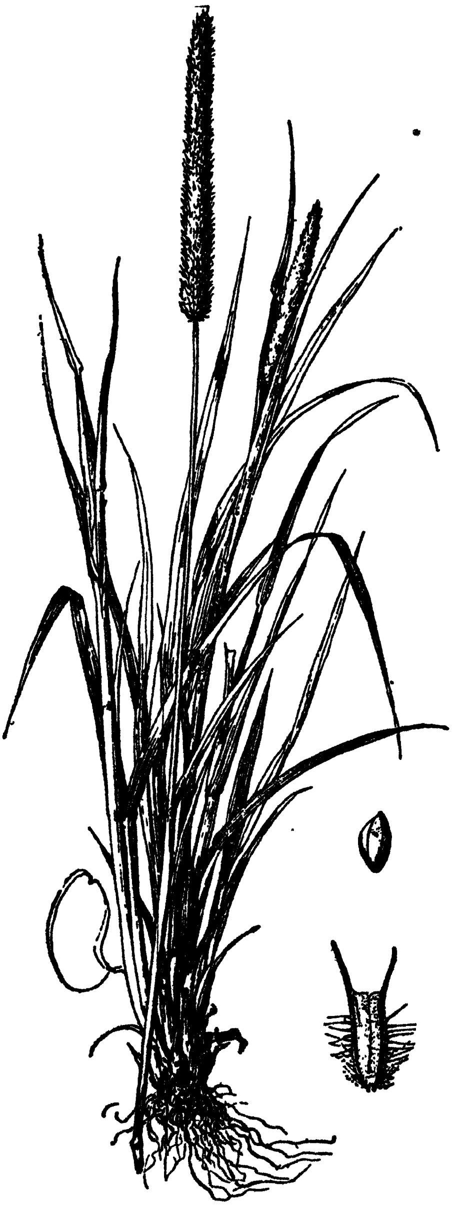

FIG. 241. — Timothy (*Phleum pratense*). (From Hitchcock, United States Department of Agriculture Bulletin 772.)

perenne and other species) probably rank in about the order named. These, with the exception of the millets and a few minor fescues and rye-grasses, are all perennial, vigorously growing plants, adaptable to a wide variety of conditions.

TIMOTHY

This (Fig. 241) is a Eurasian species which has become America's premier cultivated hay grass, probably exceeding in acreage and value all others. It is a rather short-lived perennial, reproducing not only by seed but by bulbs formed in the lower leaf axils. The inflorescence is compact and cylindrical; spikelets are one-flowered with characteristically awned and ciliate glumes.

Timothy is grown alone, but more frequently in mixture with Red Clover or Alsike Clover (*Trifolium pratense* and *T. hybridum*). It is best adapted to cool moist climates and is not important west of the Mississippi Valley States save at high altitudes. Timothy seed, which is used only for sowing, is a crop of some importance, the annual yield running between 80,000,000 pounds and 100,000,000 pounds, about half of which is grown in Iowa. From 12 to 18 per cent of the timothy seed crop is exported, chiefly to Canada.

THE MILLETS

As previously indicated, millets (Fig. 242) include a number of rankly growing annual grasses which are cultivated for forage and hay and occasionally for seed. They are among the most rapidly growing hay crops, maturing for this purpose in six to ten weeks from sowing. They are quite sensitive to cold but are drought-resistant. Millets are most grown in the Cereal Belt west of the Mississippi River. A number of millets (*Chætochloa* and *Echinochloa* species) have become naturalized as weeds of cultivation. Pearl Millet (*Pennisetum glaucum*) and Proso, Hog, or Broom-Corn Millet produce grain of some size, which in Eurasia is used for human food. In the United States, millet grain is mostly used for poultry feeding; production reached 1,311,000 bushels in 1919, but is said to have fallen off considerably since.

CANARY SEED

The common "bird seed," is the product of an annual grass; *Phalaris canariensis*, not commercially produced in the United States. Nearly 17,000,000 pounds were imported in 1928, chiefly from Argentina.

RANGE GRASSES OF THE WEST

These are of varied species, scattered over a vast, more or less arid and mountainous country. Stock are pastured here in such seasons as weather permits and generally wintered elsewhere and finished for market on grain. There is still much public domain open for grazing and grazing permits are issued, under regulations, in National Forests—scattered areas totalling about 110,000,000 acres. The total area of Western grazing lands (Fig. 240) has been estimated at over 500,000,000 acres—much of which, however, is of little worth.

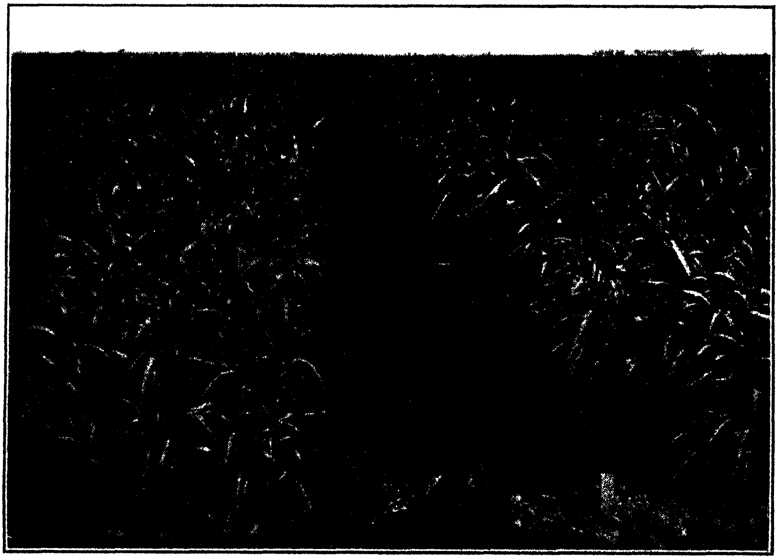

FIG. 242. — Foxtail Millet (*Chaetochloa italica*); a Valuable Annual Hay Grass. (Courtesy Bureau of Plant Industry.)

Sheep as well as cattle are grazed in this region, particularly in higher altitudes.

DAIRYING

This is a widespread industry. The greatest commercial dairying region of the United States centers north of the Corn Belt in Wisconsin (see Fig. 197). Here grass and hay production is extensively developed.

CHAPTER X

SUGAR AND SUGAR PLANTS

The Nature of Sugar

From the chemical point of view SUGAR is a group-name for a number of carbohydrates. The sugars are colorless solids or liquids which among other characteristics form sweet solutions in water. Save for lactose or milk sugar, the common sugars are plant products with the formula $C_6H_{12}O_6$ or $C_{12}H_{22}O_{11}$. Several sugars of each formula, differing in atomic arrangement, exist; of the six-carbon sugars the most common are glucose and fructose, both of wide occurrence in plants, though rarely found in large quantity. Glucose has been mentioned briefly in connection with its commercial derivation from corn starch in Chapter IX.

SUGAR, in the ordinary sense and without modification, denotes the common and commercial sugar of the formula $C_{12}H_{22}O_{11}$—saccharose or sucrose. This is found in many plants, but is stored in quantity in few, among which are Sugar Cane (*Saccharum officinarum*), Sugar Beet (a variety of *Beta vulgaris*), various Sorghums (*Sorghum* spp.), a number of palms, and the Sugar Maple (*Acer saccharum*). In considerable concentration but in small quantities and associated with glucose and fructose, sucrose is found in plant nectaries; the three sugars are associated in honey.

1. CANE SUGAR

History of the Sugar Cane

The large scale use of sugar, particularly in the temperate zones, which now consume most of it, is a rather recent development. The first plant extensively processed for sugar, *Saccharum officinarum*, is not now known in the wild state. Variously it has been conjectured to have originated in tropical Africa, in south Pacific islands, and in India. In the last of these regions its culture antedates history. Cane culture seems to have been spread by the Arabs in the Middle Ages into Egypt, Sicily, and to Moorish dominions in Spain. Portuguese navigators transported it to Madeira and the Canaries in the fifteenth and sixteenth centuries. It was early established in Spanish and Portuguese provinces in the New World—in Santo Domingo, it is said, in 1494, two years after the first voyage of Columbus. Less than twenty years later, several cane-crushing mills were in operation on that island. Into Cuba, the present-day "world's sugar bowl," the cane came somewhat later; in 1760 the sugar production of Cuba was 4,400 tons.

Large-scale use of sugar expanded with growing use of sweetened beverages—tea and coffee—in the eighteenth century. During the American colonial period sugar, molasses, and rum (the last from fermented molasses) were staple and major articles of trade from the West Indies to New England and to Europe.

Jesuit missionaries introduced sugar cane to New Orleans about 1750, but it was never an important crop there until the neighboring English colonies had attained their independence. Early in the nineteenth century, cane production and sugar manufacture were accelerated by failure of indigo and other crops, as well as by the purchase of Louisiana Territory from France in 1803. From 1820 to 1860 Louisiana production increased rapidly. After almost disappearing during the Civil War, Louisiana production rapidly increased until about 1904. Then it fell off rapidly because of cane disease and other unfavorable conditions. Its more recent history will be noted briefly in a later paragraph.

The Sugar Cane Plant

Saccharum officinarum (Fig. 243) is a perennial rhizomatous grass with solid stems one to two inches in diameter and six to fifteen feet tall. The leaf-blades are two to three inches wide and a yard or more in length.

Sugar cane seldom blooms in the United States, and seed is formed still more rarely. Spikelets are hairy, borne in pairs on plume-like branches of a huge spreading panicle. The grain is very small, and germination is poor. In field culture, the plant is propagated by stem cuttings from the lower joints. Cuttings are set either in spring or fall; in Louisiana, fall-planted cane is liable to injury. Being perennial, sugar cane will sprout year after year from underground parts; in Louisiana, more than two successive crops are not likely to be profitable.

In the tropics, fruiting of sugar cane is more common. Particularly in Java, extensive breeding experiments have been carried on, through which strains have been developed which are resistant to mosaic and various other diseases and insect pests.

Sugar cane is characteristically a plant of hot, frostless tropical regions where heavy showers are quickly followed by blazing sunshine. Its range in the United States is shown in Fig. 244. The plant is rather out of its element even in Louisiana and the Southern States; thus, probably, it is there predisposed to

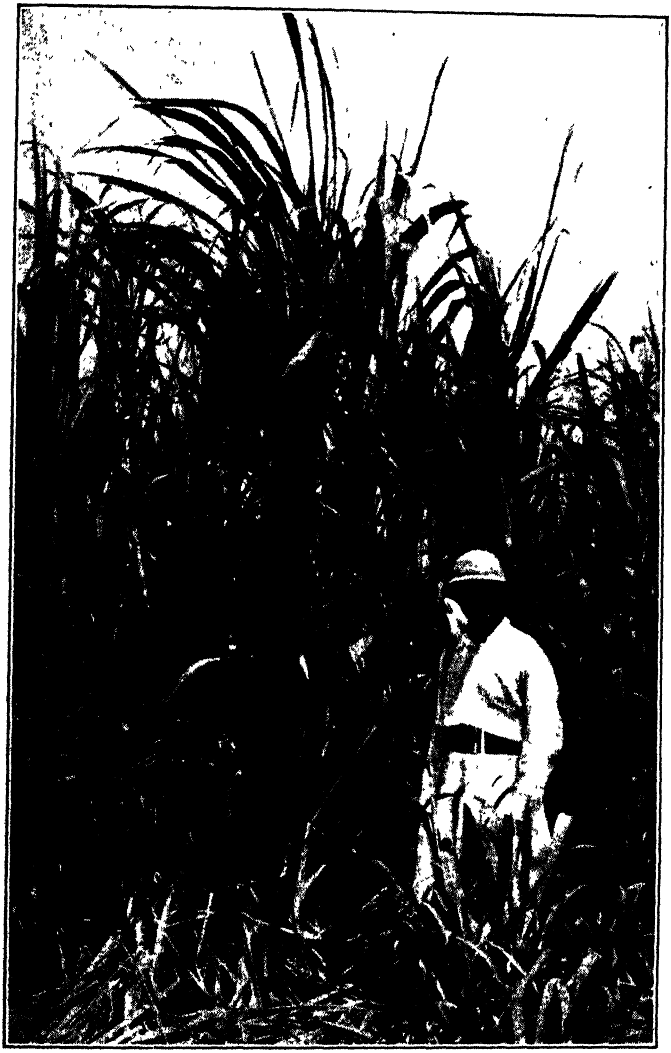

FIG. 243. — Sugar Cane (*Saccharum officinarum*). (Courtesy of United Fruit Company.)

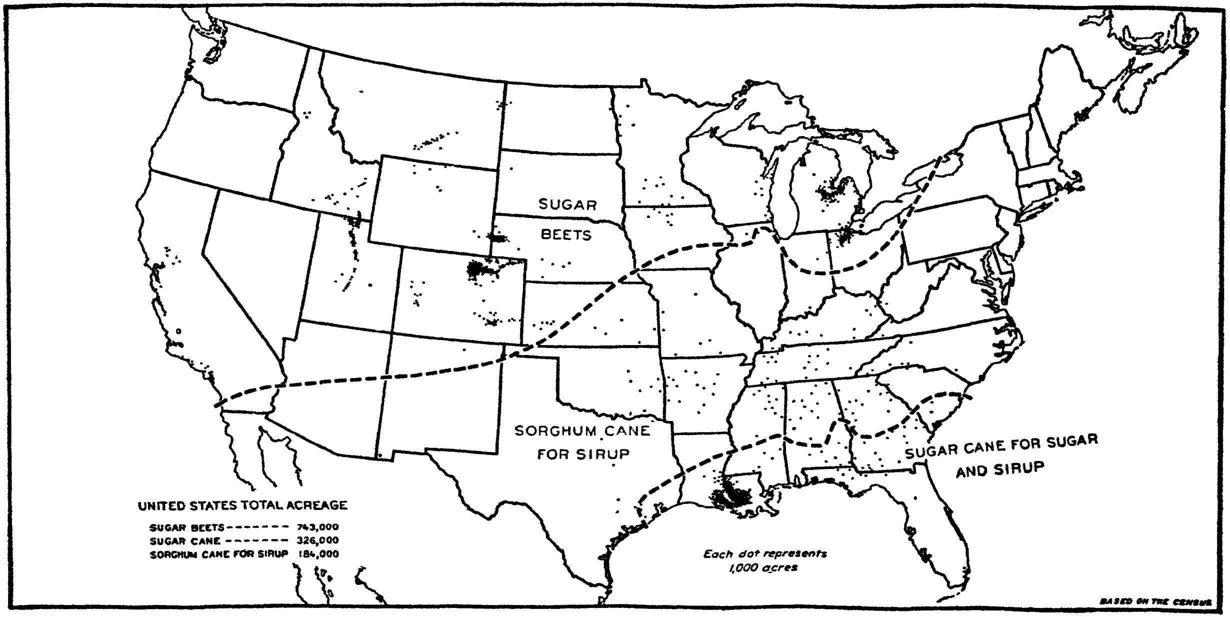
SUGAR BEETS
SORGHUM CANE FOR SIRUP
SUGAR CANE FOR SUGAR AND SIRUP
UNITED STATES TOTAL ACREAGE
SUGAR BEETS ------- 743,000
SUGAR CANE ------- 326,000
SORGHUM CANE FOR SIRUP 184,000
Each dot represents 1,000 acres
BASED ON THE CENSUS

FIG. 244. — Acreage of Sugar Crops in United States, 1924. Sugar beets do not, in general, show a sufficiently high sugar content to be manufactured profitably where the summer temperature is over 72° and where the beets must consequently compete with corn for the farmer's labor. Sugar cane is not grown in large amounts for sugar outside of the almost frost-free lower Mississippi Delta of Louisiana. The broad belt between the sugar-beet and sugar-cane areas is occupied by a thin, scattered acreage of sorghum cane. Acreage of sorghum cane in 1924 was less than half that in 1919. (From United States Department of Agriculture *Yearbook*, 1928.)

disease and insect damage. Among other handicaps to its culture there, the frost-free season—about 250 days—does not suffice thoroughly to ripen the cane. It is therefore cut in a somewhat immature condition in which its sugar content is lower than that of more tropical regions, such as Cuba. Unripe cane, moreover, contains sugars other than sucrose, which do not crystallize in manufacture and which retard crystallization of the sucrose. Frost-warning service of the United States Weather Bureau is a valuable aid to Louisiana planters, who retain large forces of men to cut the crop when cold weather threatens.

FIG. 245. — Plowing Cuban Land for Replanting. (Courtesy United Fruit Company.)

Cane culture requires considerable labor, and in a climate with alternate growing and dormant periods, such as that of Louisiana, there is the problem of seasonal rush, not felt in the tropics. Aside from Louisiana, cane sugar can be profitably produced in the continental United States only in southern Texas and southern Florida, and in both regions the industry is small. For syrup production only, the cane is grown somewhat further north in the Gulf States.

Cuban Cultivation.—Sugar is the main agricultural and business interest of Cuba. There production and manufacture are largely controlled by American capital. The cane is chiefly grown on large, efficient sugar plantations, equipped with mills, railroad facilities, and small armies of laborers. Virgin land is covered with a dense tropical growth of timber and underbrush, some species valuable, some not. After clearing it is plowed by steam power, tractors, or bull or ox-plows—the latter largely used in small tracts—and pulverized by harrows. Cane is planted either in spring or fall, preferably after a fairly heavy rainfall. Cuttings are laid at seven-foot distances in rows seven feet apart. They are taken from plants not over a year old and from the median portion of the canes; each has three buds or "eyes." These are thrust into holes made with mattocks or sticks and about two inches of earth trodden over the upper ends. As fire is the principal hazard of cane cultivation, frequent fire-lines are left; these may be planted with sweet potatoes and other crops, which furnish food for the laborers and also, through their green and succulent growth, reduce fire-hazard. The cane sprouts appear in about two weeks after planting, and the first crop is mature in from a year to fifteen months. The second crop, or "first ratoons," is removed about a year after the harvesting of the first. The number of successive ratoon crops depends largely upon the character of the soil; six, eight, and even more may be gathered on virgin soil. When yields become unprofitable, fields may be burned over, plowed, harrowed, and replanted.

FIG. 246. — A Tractor at Work on a Cuban Sugar Plantation. (Courtesy of United Fruit Company.)

The Manufacture of Cane Sugar

Harvesting the cane consists in stripping leaves and removing the upper end of the stem, hand-cutting the cane at the base and shipping it to the factory. Harvested cane is very perishable; the sooner it is processed, the better. In Louisiana, where cane-cutting may be delayed till the threat of cold weather, frost endangers cane awaiting grinding. In Louisiana, and also in Cuba, large plantations maintain their own branch railways to carry the cane to the mills. For delivery to the railway, carts are used; in Cuba a caterpillar cart, drawn by cattle, is much employed. The stripping, cutting, transporting, grinding, and processing of the product require "a coördination of big-scale operations not approached by any other agricultural enterprise . . . (and) . . . the necessity for organization of a transportation system and a rigid discipline in all related activities comparable in its efficiency to the service of supply in a modern army." [1]

Details of modern sugar manufacture differ somewhat in various parts of the world. Some very primitive processes in the Philippines are shown in Figs. 247–248.

Factory processes involve crushing and extracting juice; its clarification and evaporation, the formation of crystals and the separation of the crystals from the molasses. The final product of the local mill is raw sugar, light brown in color, and approximately 96 per cent pure. Further purification and the final granulation is done at a refinery. Whereas the primitive sugar mill consisted of nothing more than a hollow tree-stump in which a log, shaped into a huge rude pestle, was revolved by cattle-power, modern plants in Louisiana and Cuba are huge affairs, highly mechanized, some grinding 4,000 tons or more of cane per day.

The following is a description of the grinding process in Louisiana:

"The juice is extracted from the cane by means of heavy steel horizontal crushers and rollers driven by powerful steam-engines. The cane passes first between two crushers, which are rollers with interlocking teeth of various design on their faces. Here the cane is pressed into a mat of even thickness. It passes by means of an endless carrier to the first set of rollers which are arranged in a group of three—two below and one above. In most modern mills there are three to four such groups of rollers arranged in tandem. As the mat of cane passes in a horizontal

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[1] E. W. Brandes, *et al.*, "Sugar," United States Department of Agriculture *Yearbook* 1923, p. 176.

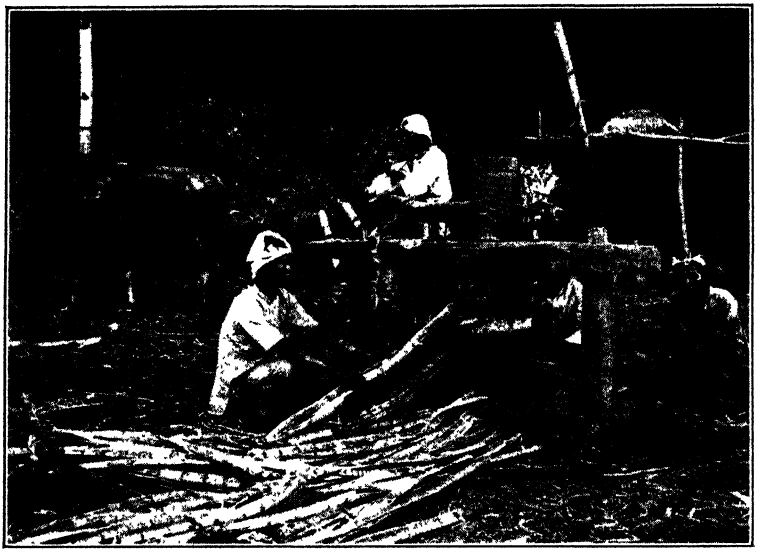

FIG. 247. — Crushing Sugar Cane in the Philippine Islands. (Photo from Philippine Bureau of Science.)

FIG. 248. — Cooking Sugar Cane Juice in the Philippines. (Photo from Philippine Bureau of Science.)

direction from one set to the next, it is sprayed with hot water to dilute the remaining juice and facilitate a more complete extraction. After passing the last roller the mat of extracted cane fiber, or bagasse, is carried on another endless conveyor to driers or directly to the furnace, where it is used for fuel to operate the mill.

"The juice flowing downward from the sets of rollers is first strained to remove suspended matter. It passes through a juice-heater, where the temperature is raised to 190–200° F., thence into settling tanks. After about one-half hour the fairly clear juice is drawn off, leaving a deposit of dirt in the bottom of the tank. The juice is further clarified by the addition of lime. Sulphurous acid or other chemicals may also be used, depending on the methods followed in individual mills. All methods have for their purpose the precipitation of impurities, which are afterward filtered out, or the decomposition of reducing sugars into organic acids. The settlings and scum from juice-heaters and settling tanks are treated separately, and the clear liquid recovered from them is added to the main body of clear juice, which is evaporated to sirup under partial vacuum in the so-called 'effects.' The sirup may or may not be further clarified and filtered at this point, depending on the details of the process used. It now passes into the vacuum pans where it is boiled at low temperatures under greatly reduced atmospheric pressure. After long-continued boiling the sirup becomes very thick and concentrated, due to evaporation of water, and small crystals of sugar begin to appear in the heavy viscous liquid. These crystals grow in size with the introduction from time to time of fresh sirup. When the crystals are of proper size the magma of crystals and mother liquor known as 'massecuite' is passed on to the centrifugals, where the next operation of separating crystals from the mother liquor (molasses) takes place. Usually the molasses is not entirely exhausted of sugar and is returned and boiled again in the vacuum pan, either alone or with the addition of fresh sirup. The process may be repeated several times.

"The centrifugal machines, of which there are usually a large number, known technically as a 'battery,' consist of vertical cylindrical baskets enclosed in jackets. The sides of the baskets are perforated and in addition are lined with fine-mesh wire-gauze strainers. The baskets are revolved at high speed and the molasses is thrown out against the sides of the outer jacket and drops into a gutter below. The crystals are retained in the baskets and are washed quickly with water while revolving to remove the film of molasses. The sugar is scraped with paddles from the sides of the baskets as they revolve and is carried through tubes to driers, then to a spout where it is bagged or barreled."[1]

Cane Syrup Manufacture

The thick, viscous liquid well known as molasses is a by-product of sugar manufacture; besides its use in cooking and baking, large quantities are used for stock-feeding. Cane syrup is quite a different first-product of a considerable region in the South where cane does not mature sufficiently for profitable sugar production; besides sucrose, it contains a proportion of non-crystallizing sugars. Cane syrup is mostly made in small plantations (Fig. 249) and local mills (Fig. 250), and is largely utilized for table use in the producing States. Faulty methods of production have restricted the market for cane syrup, but these are being overcome to some extent. It is much used to mix with corn syrup and maple syrup.

2. Beet Sugar

History of the Sugar Beet

The sugar beet is a very recent rival of the cane. The existence of sugar in beets was demonstrated by Marggraf of Berlin in 1747, but the discovery attracted little attention at the time. Commercial development began in Germany and France about 1800. High prices of sugar during the Napoleonic wars promoted the beet industry, but owing to imperfect methods of manufacture and governmental vicissitudes in producing countries little real headway was made before 1830. During the remainder of the nineteenth century the European sugar beet industry was actively promoted by governmental bounties. These artificial aids brought about decided overproduction, and distress was felt in tropical countries, particularly in British possessions, where cane sugar production was an important interest. In 1903, after many years of fruitless negotiation between governments concerned, an arrangement was consummated by which it was agreed to suppress all bounties which might benefit the production or export of sugar. This agreement remained in force until 1913, soon after which the outbreak of the World War brought disorganization of all trade. At that time the production of beet sugar was somewhat less than that of cane.

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[1] E. W. Brandes, *et al.*, *loc. cit.*, pp. 181–183.

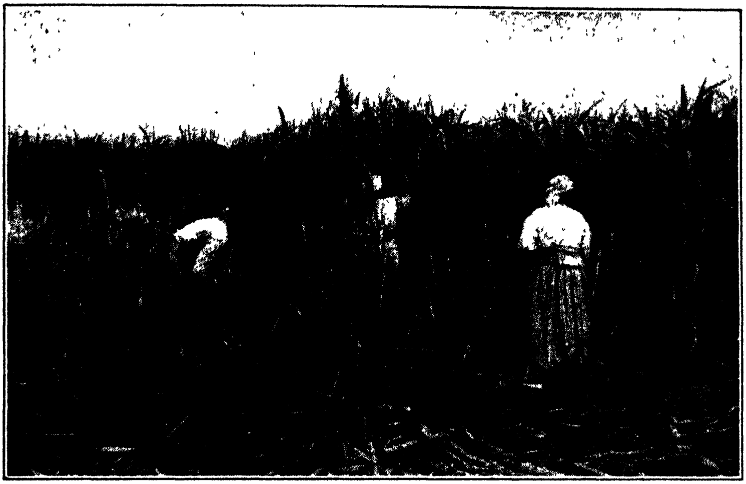

FIG. 249. — Harvesting Sugar Cane in Georgia, for Cane Syrup. (Courtesy of Bureau of Plant Industry.)

FIG. 250. — A Cane Syrup Mill on a Small Farm. The crushing device is seen in the center; pressure is applied through the sweep drawn by the mules, whose circular path is shown. The juice is concentrated in an open pan under the shed. There are now many more modern mills in which stream or electric power is used, and improved evaporators employed. (Courtesy of Bureau of Plant Industry.)

Sugar beet culture in the United States has become an important industry during the present century, particularly since 1920. In seven of the eleven years ending 1930–1931 American production has passed 1,000,000 tons.

The Sugar Beet Plant

All cultivated beets are considered varieties of *Beta vulgaris*, itself probably a derivative af *Beta maritima*, the wild beet of southern Europe. *B. maritima* is a perennial; cultivated races are ordinarily biennial, producing the first year an extensive underground system from which proceeds a rosette of large, fleshy-petioled leaves. The most obvious part of the underground system is a turnip-shaped or elongated tap root (Fig. 251), richly charged with water and sugar, which merges into a blunt crown or modified stem from whence proceed the leaves and the branching, flowering stem of the second year (Fig. 252). This storage region in cross-section reveals a peculiar zonate growth resulting from several cambium formations, characteristic of the Chenopodiaceæ, to which family the beet belongs. The sugar is said to be mostly in small parenchyma cells, whereas larger ones are distended with water. Ramifying from the swollen center is a widely spreading growth of fibrous roots, extending to a considerable depth.

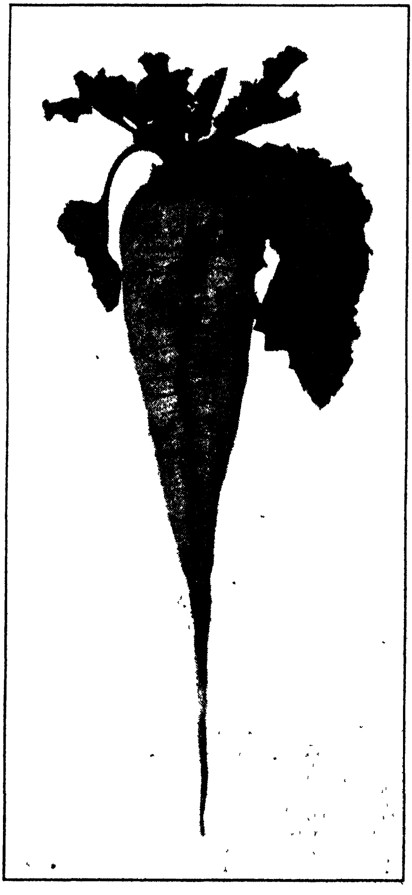

FIG. 251. — A Well-Grown Sugar Beet. (Courtesy of Bureau of Plant Industry.)

The sugar beet shows considerable varietal difference in size and shape of root. Usually the flesh is white, in distinction to the red or yellow tissues of table and stock-feeding varieties. Sugar content varies from 12 to 16 per cent.

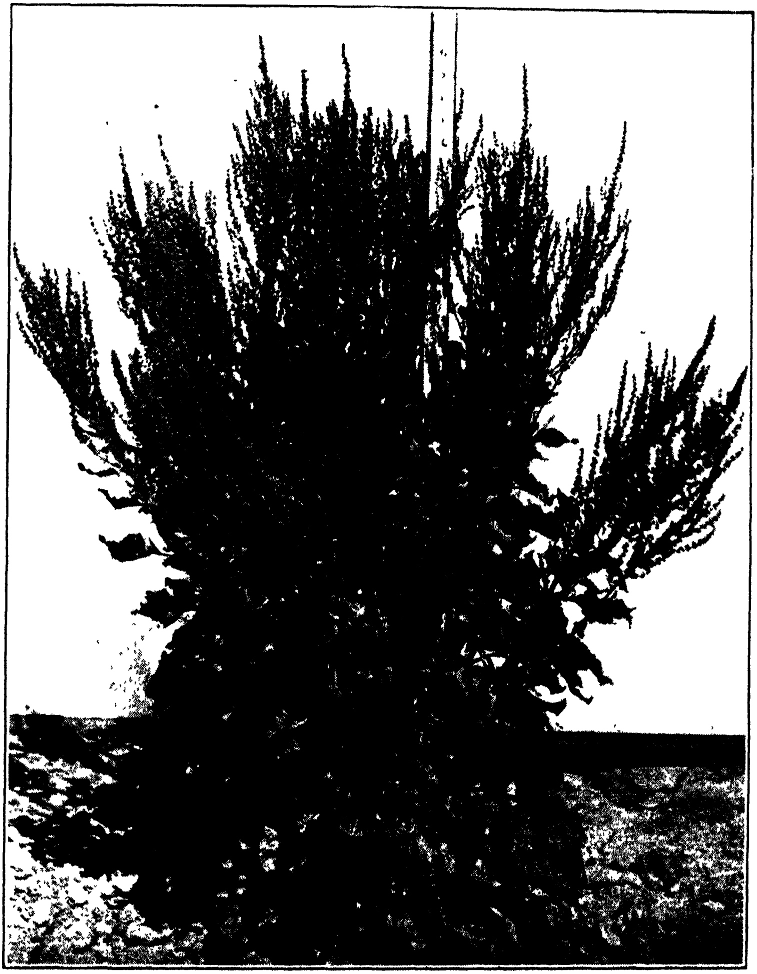

FIG. 252. — A Seed Plant of the Sugar Beet. (Courtesy of Bureau of Plant Industry.)

The sugar beet is a medium-season crop, requiring about five months to mature. It is thus suited for culture throughout a wide range in Europe, which is the principal continent of beet sugar production. With the exception of certain regions in California, the crop is grown in the United States mainly in the northerly belt of States and in western mountain regions where the summer temperature averages about 70° F. Warm weather during the growing season is desirable; this may be followed by lower temperatures toward maturity. Probably 75 per cent of the American crop is raised on rich dark silt and clay loams. Constant moisture, which often must be secured by irrigation, is essential. Much hand labor in thinning, cultivation, and harvesting is required. The crop has its full share of insect pests and diseases.

Sugar beet growing is a large-acreage proposition, and, with its associated manufacture, is an important local industry where it is carried on. Colorado, Wisconsin, and California are the principal beet-producing States.

Harvesting Sugar Beets.—Sugar beets are generally grown under contract to large factories centrally located in producing regions, whose representatives inspect the growing crop, and, by testing samples, determine date of harvest. Beets are lifted, thrown into windrows, topped by hand, and hauled, usually by wagon or truck, to sugar mill or loading station.

Manufacture of Beet Sugar

At the factories the beets are cleaned, washed, and sliced by machinery. The slices are treated repeatedly by hot water in large cylinders. This diffusion process of extraction is thus distinctly different from the crushing of cane. The water extract is treated with carbon dioxide, which precipitates the considerable quantity of lime in the beet juice; and with sulphur dioxide which acts as a bleaching agent. Calcium carbonate and other impurities are removed by filtration, after which the filtrate is concentrated and repeatedly crystallized under partial vacuum. Like most mechanical processes, the diffusion process of extraction of beets is subject to difference in detail, particularly as regards the recovery of the final fractions of sugar. From a theoretical viewpoint, the usual procedure is rather wasteful, as sugar is recovered from only about 65 per cent of the beet liquid, the rest being discarded in the various steps of the process.

Beet sugar from a modern refinery is purified and granulated sufficiently for all ordinary uses.

3. The Use and Production of Sugar

Uses of Sugar and Its By-Products

Sugar is extremely high in energy values, although totally lacking in nitrogenous material or vitamins. It has been estimated that sugar provides about 13 per cent of all the food energy obtained by the people of the United States. Our per capita consumption is about two pounds per week, doubtless the highest in the world.

The food uses of sugar and its various grades are too well known to require comment. Its flavoring use in foods and medicines, which is considerable, derives from its capacity to disguise strong or undesirable flavors without—ordinarily at least—any chemical reaction with the substances involved. Lemonade, for example, is really as sour (acid) after sweetening as before.

Molasses of cane sugar, the liquid viscous residue containing —besides sucrose—invert or uncrystallizable sugars, is extensively used, the best grades for human food and poorer grades— black strap—for stock-feeding. In tropical countries molasses is fermented and distilled for rum; in the United States it is a source of industrial alcohol. Beet molasses is not sufficiently palatable for human food, but is somewhat used for stock. So also is the pulp from beet factories, which may be dried and stored for future use. Bagasse of cane sugar mills, mixed with petroleum, is used as fuel in the mills which produce it. Surplus bagasse may be used in paper and insulating board manufacture, and as fertilizer.

Sugar beet tops and cane-tops are used for stock-feeding; either may be preserved as ensilage. As yet the wastes of sugar manufacture are considerable; it is perhaps only a question of time before much material now unused will yield valuable products.

World Production of Sugar

Between the sugar beet of the temperate zone and the tropical cane, sugar production is a world-wide industry, one of the greatest of agricultural interests, and not small among manufacturing processes. A statistical summary of production appears in Table X.

The pre-war world output of raw sugar varied between 16,000,000 and 21,000,000 short tons, of which rather more than 50 per cent was cane sugar. About 80 per cent of the beet sugar crop was from combatant nations; the bulk of it from Germany,

TABLE X

Sugar, World Production, in Thousands of Short Tons for Years Indicated

CROP YEAR [1]	*Estimated world total*	*Estimated world total cane sugar*	*Estimated world total beet sugar*	PRODUCTION IN SELECTED COUNTRIES							
				United States [2]	*Cuba*	*India* [3]	*Java* [4]	*Germany* [5]	*Czechoslovakia*	*Poland* [6]	*France* [7]
1909–10	16,828	9,670	7,158	883	2,021	2,481	1,411	2,147	......	....	861
1910–11	18,834	9,870	8,964	903	1,661	2,587	1,617	2,770	......	....	763
1911–12	17,908	10,622	7,286	1,005	2,124	2,745	1,550	1,552	......	....	546
1912–13	20,542	10,896	9,646	907	2,720	2,862	1,616	2,902	......	....	1,029
1913–14	21,154	11,640	9,514	1,089	2,909	2,573	1,549	2,886	......	....	841
1914–15	20,875	11,952	8,923	1,023	2,922	2,736	1,454	2,721	......	376	355
1915–16	18,885	12,278	6,607	1,078	3,398	2,949	1,797	1,678	......	239	159
1916–17	18,592	13,255	5,337	1,193	3,422	3,093	2,009	1,721	......	293	217
1917–18	20,293	14,790	5,503	1,068	3,890	3,839	1,960	1,726	......	263	235
1918–19	18,604	14,076	4,528	1,102	4,491	2,752	1,473	1,297	[8] 714	249	129
1919–20	17,989	14,338	3,651	903	4,184	3,404	1,681	774	553	106	182
1920–21	19,546	14,225	5,321	1,347	4,406	2,825	1,853	1,195	797	195	358
1921–22	20,578	15,095	5,483	1,425	4,517	2,928	1,994	1,434	731	170	326
1922–23	20,860	15,127	5,733	1,022	4,083	3,410	1,981	1,604	811	335	522
1923–24	22,810	16,306	6,504	1,112	4,606	3,715	2,201	1,263	1,115	423	524
1924–25	26,670	17,712	8,958	1,260	5,812	2,852	2,535	1,724	1,574	540	919
1925–26	27,989	18,813	9,176	1,120	5,524	3,334	2,175	1,763	1,662	638	831
1926–27	26,624	18,125	8,499	1,011	5,050	3,659	2,639	1,834	1,153	634	786
1927–28	28,515	18,671	9,844	1,246	4,527	3,603	3,238	1,846	1,383	658	956
1928–29	30,655	20,319	10,336	1,273	5,775	3,035	3,198	2,054	1,165	824	999
1929–30	30,607	20,459	10,148	1,294	5,231	3,092	3,245	2,188	1,142	1,010	1,011
1930–31	31,858	19,116	12,742	1,482	3,495	3,604	3,095	2,808	1,260	863	1,324
1931–32 [9]	29,321	19,809	9,512	1,400	2,915	4,446	2,821	1,758	896	544	942
1932–33 [9]	26,860	18,165	8,695	1,629	2,240	5,209	[10] 1,433	1,157	686	459	990

Austria-Hungary, Russia, and France, in the order named. Cane sugar was chiefly derived from Cuba and from Dutch and English tropical dependencies, particularly India and Java; and from the United States, including Hawaii, Porto Rico, and the Philippines. Strenuous efforts were put forth by all belligerent nations not only to conserve sugar and control its use but to stimulate cultivation. Beet-sugar-making, nevertheless, was drastically reduced, especially in France, where the most of the productive and refining regions were occupied and devastated. Russia, after the revolution, was not a factor in world commerce. The world beet-sugar yield for war years is somewhat uncertain; for the post-war year 1920–1921 it has been estimated at 5,294,000 tons as compared with a 1909–1913 average of 8,297,000 tons. Cane sugar production increased during the war, particularly in Cuba. High prices during immediate post-war years were mainly speculative. By 1928–1929 both cane and beet sugar had reached the highest production in history; in that year and the next, decided over-production was evident, particularly in Cuba, whose cane sugar crop for 1928–1929 was about 17 per cent of the world's record total of 30,697,000 tons of cane and beet sugar. Java came next with 3,238,000 tons. Germany led in beet sugar with 2,054,000 tons—a quantity almost as

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From United States Department of Agriculture *Yearbook*, 1933. Bureau of Agricultural Economics. Estimated world total sugar production for the period 1895–96 to 1908–09 in Agricultural Yearbook, 1924, p. 808.

[1] Figures are for the crop years 1909–10 to 1932–33 for the countries in which the sugar production season begins in the fall months and is completed during the following calendar year, except in certain cane-sugar producing countries where the season begins in May or June and is completed in the same calendar year. Production in these countries is for the calendar years 1909 to 1932.

[2] Production of cane and beet sugar in terms of raw sugar.

[3] The figures quoted for India are for the production of gur, a low grade of sugar polarizing between 50° and 60°. Practically the entire crop is consumed within the country.

[4] All grades of sugar reduced to terms of head sugar, a grade of sugar which contains at least 96.5 per cent sucrose. Figures for Java are for the calendar years 1910–1933.

[5] Figures for 1909–10 to 1917–18 are for pre-war boundaries.

[6] Figures are incomplete through 1920–21; 1914–15 includes Prussian Poland only; 1915–16 to 1919–20 include Prussian Poland and Congress Poland; 1920–21 includes Prussian Poland, Congress Poland, and Galicia.

[7] Figures for 1909–10 to 1918–19 refer to pre-war boundaries; 1914–15 to 1918-19 are exclusively of invaded territory.

[8] Bohemia, Moravia, and Silesia only.

[9] Preliminary.

[10] Unofficial estimate.

great as she had, before the war, produced in larger territory. Another major producer, India, had a crop of over 3,000,000 tons, but most of India's product is low-grade sugar and locally consumed.

In 1929–1930 the world sugar crop nearly equaled that of the preceding year, but in subsequent years it has decidedly decreased. The drop has been particularly abrupt in Cuba, which in 1932–1933 produced but 38.7 per cent of its crop of 1928–1929. The story of the debacle of the Cuban sugar industry, with its aftermath of national bankruptcy and revolution, is far too complex to be related here.

In Hawaii, Porto Rico, and the Philippines the volume of sugar continues to increase; in total sugar production the United States and its possessions stands second only to Cuba. Inasmuch as the major portion of the Cuban crop is handled by or through American nationals, and as the per capita sugar consumption of our 124,000,000 people exceeds that of any other nation, the United States may be considered the dominant factor in the world's sugar trade.

Production and distribution of the world's sugar has been complicated not only by governmental bounties which have been mentioned, but by various forms of taxes. Practically all nations which produce or refine sugar have import duties designed to protect domestic industry, and other nations impose duties and taxes for revenue. Sugar, in fact, is one of the most universally taxed articles of commerce; the whole subject of sugar imposts, with their bearing not only upon internal policies but the international relationships of nations, is beyond the scope of the present volume.

4. SUGARS OTHER THAN CANE AND BEET

While cane and beet sugars thoroughly dominate the world's market, there are several other sucrose-containing products of sufficient importance to deserve mention.

Palm Sugar

JAGGERY is an Indian vernacular name for a sugary product of several palms, particularly the Wild Date (*Phoenix sylvestris*) of the Ganges valley. The sap, known as toddy, is collected during several months of the cool season and is concentrated to a crude raw sugar by native processes. Jaggery is consumed in India.

Several other tropical palms yield saccharine products of more or less importance in native economy, which do not figure in Occidental trade.

Sorghum

As already noted (Chapter IX) the genus *Sorghum* yields several agricultural products. The term SORGO is applied to sorghum varieties grown for syrup production. Sorgo (Fig. 253) is a crop of shorter season than cane; production in the United States is widely scattered, centering mostly in the Southern States. About 1879 sorgo was, proportionally, a much more important crop than it has been since. War conditions stimulated a declining industry to a peak production of over 45,000,000 gallons in 1921. In 1930, production had fallen to 24,132,000 gallons.

Sorghum juices are locally evaporated in small establishments, and the product is chiefly used in the region of origin.

FIG. 253. — In a Field of Sorgo. (Courtesy of Bureau of Plant Industry.)

Maple Sugar

From the commercial point of view this commodity is of little significance, but there is much of general interest in the product and its making.

Probably all species of maple (*Acer*) produce a saccharine sap, but use is quite strictly limited to that of the Sugar, Rock, or Hard Maple (*Acer saccharum*), an important timber tree of the northeastern States.

Maple trees are "set" in early spring, when snow still covers the ground (Figs. 254–256). The sapwood is penetrated—tapped—with a small auger; a channeled or tubular spout is driven into the hole, and a bucket attached. Clear, warm days following sharp, frosty nights bring forth the largest "runs" of clear, watery sap, with a slight saccharine flavor. The daily yield of a tree may be three or four gallons of sap, and the season's "run" may continue intermittently for a month or more. Often several

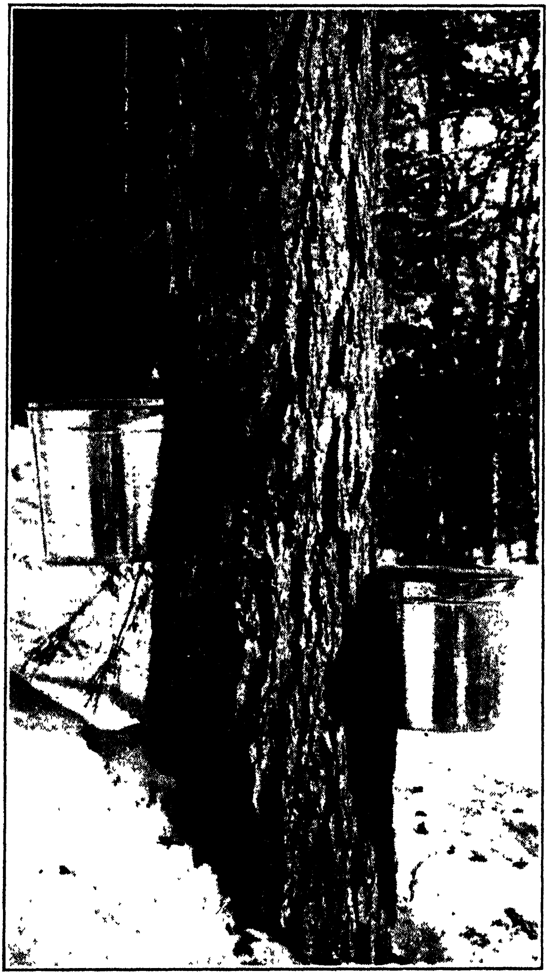

FIG. 254. — A Sugar Maple with Two Buckets. These are covered to keep out rain and dirt. (Courtesy of Bureau of Chemistry and Soils.)

days of unfavorable weather may pass with no "run" worth collecting. The gathered sap is boiled in flat-bottomed, partitioned evaporators. Rapid boiling yields a light-colored, high-grade product; prolonged cooking, a dark, strongly flavored sugar or syrup. On the average, a tree yields a little over two pounds of sugar, or about a quart of table syrup, per season.

Maple sugar was first made by Indians, who boiled the product in crude kettles or concentrated it by partial freezing. In colonial days it was an important sweet of New England housewifery. In recent years, owing to lumbering of sugar orchards, abandonment of farms, and small profits of manufacture, production tends to decrease. Maple-sugar-making is purely a small-scale farm industry; were it not that the season occurs when there is little other farm work, production would be still more limited.

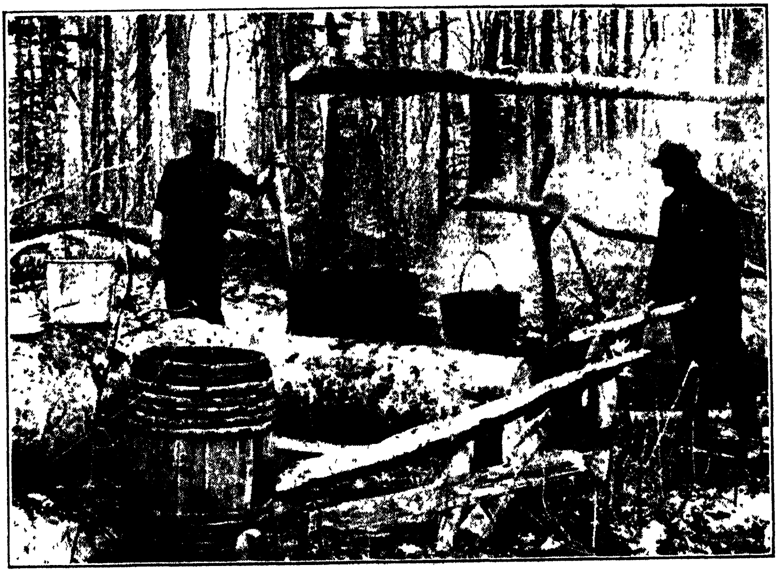

FIG. 255. — The Old-Fashioned Way of Boiling Maple Sap in Open Kettles in the Maple Orchard. This method yields a dark syrup, likely to be flavored with ashes and smoke. (Courtesy of Bureau of Chemistry and Soils.)

Vermont and New York lead in maple sugar production. Other New England States, and those bordering on the Great Lakes, account for nearly all the rest.

The sugar of maples is nearly all sucrose, with small quantities of invert sugar; the characteristic flavor is due to small quantities of other constituents of the sap. Maple sugar is commonly marketed in cakes of various sizes. Its water content is somewhat above that of cane or beet sugar. The color varies from pale to deep brown. Maple syrup is at present more largely sold than maple sugar; it is a rich clear-brown liquid evaporated to a point just short of crystallization. This is prized as a table delicacy; it is much mixed with less expensive corn and cane syrups.

Maple products are largely used in flavoring tobacco, and in confectionery and ice creams. While it is illegal to sell a mislabeled maple product, the flavor is more or less skilfully imitated.

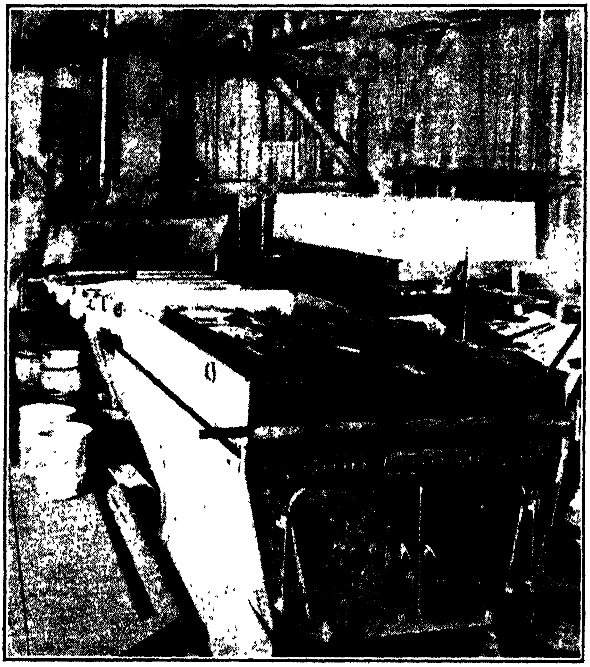

FIG. 256. — An Interior View of a Sugar-House in a Maple Orchard. The pan is broad and shallow, with several compartments; the syrup concentrates as it passes from one to another. The fire is in the iron "arch" underneath. (Courtesy of Bureau of Chemistry and Soils.)

Honey

The majority of showy flowers produce a sugary substance called nectar, which after partial digestion and storage by bees is termed honey. In the collection and gathering of the nectar, the bee obtains food and the plant secures transportation for its pollen. This symbiotic relation between nectar-seeking insects and plants is one of the most remarkable commonplaces of nature.

The individual flower-yield of nectar is small, quite beyond the practicability of human collection. Yet in the aggregate it reaches immensity. From the nature of things, American flower-sugar production is quite impossible of close calculation, but expert apiculturists consider it to be far beyond the cane and beet sugar consumption of the American nation. Honey, undoubtedly, was the first concentrated sweet of our savage ancestors. Among numerous nectar-seeking organisms only the honey-bee stores enough to be worth systematic robbery, which may have been practised long before any animals were tamed. To-day descendants of cave men assure shelter, protection, and food to this one of the very few insects which, in any desirable sense, may be termed domestic.

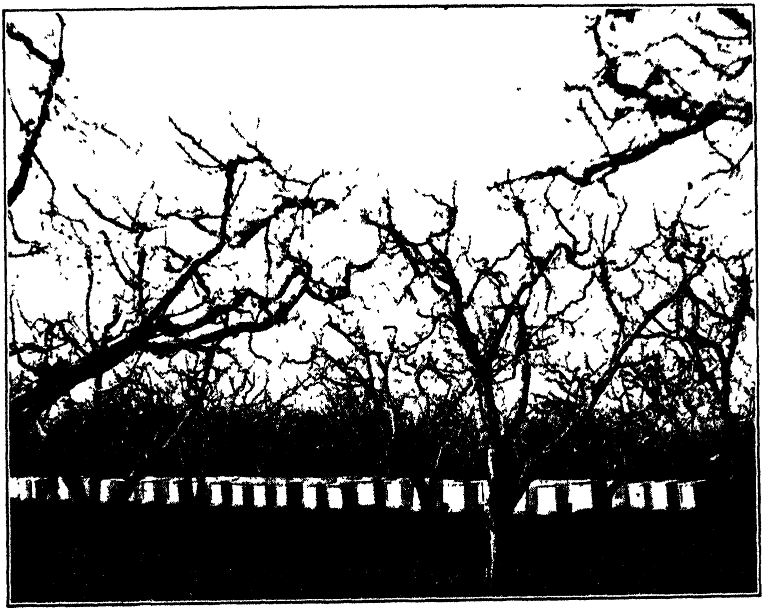

FIG. 257. — Beehives in a Plum Orchard. (Courtesy Bureau of Plant Industry.)

Bees gather nectar and pollen for food for themselves and their young; reserves are stored for consumption when nectar-flow ceases. It has been estimated that a colony utilizes over 400 pounds of honey per year for its own sustenance; surplus honey, attachable by the bee-keeper for rent of hive and orchard, averages about fifty pounds and is often much less. Slight differences in seasonal nectar-flow, inadequate management of apiary, appearance or freedom from bee-disease, may spell success or failure for the apiarist and may affect, favorably or not, the pollination processes upon which so much of agricultural profit depends.

American bee-keeping is such a scattered, small-scale industry that statistics are difficult to gather. Census figures, showing the relatively large-scale production alone, total about 55,000,000 pounds annually; it is estimated that total output may be four times that.

Leading States in honey production are California, those of the intermountain region—Idaho, Wyoming, Utah, and Colorado—and New York and the North Central states.

Plants important in honey production are quite too numerous to mention. Members of the Leguminosæ, especially alfalfa and white clover, are prominent. So also are buckwheat, the citrus fruits, eucalypti, lindens, and various Labiatæ.

Nectar probably consists largely of sucrose; partial digestion by the bee converts a portion of this to invert sugar—a mixture of dextrose and levulose. Honey is nearly a pure sugar product, with the energy values and vitamin deficiencies of the class. Presence or absence of very small amounts of characteristically flavored or aromatic substances brings about wide variations in palatability and value of honey. As compared with the common sugars, it is a high-priced table luxury. Dietitians consider it more easy of digestion than most sugar products.

CHAPTER XI

THE FIXED OILS

The Nature and Occurrence of Fixed Oils

The oils discussed in this chapter are known as FIXED or EXPRESSED oils and also as NON-VOLATILE oils. The last term is applied in distinction from the VOLATILE, distilled, or essential oils, whose vapors are volatilized by steam. These are a miscellaneous group of plant products, unrelated to the true oils; some of them will be noted in Chapter XIV, dealing with aromatic products.

Fixed oils are compounds of glycerine with certain complex organic acids—oleic, palmitic, and others—which are known as fatty acids. The difference between an oil and a fat is mainly a convention; the term OIL is used to denote a substance which assumes the liquid phase at ordinary temperatures, while a FAT is one which is solid. Most vegetable products of the nature under discussion are thus classifiable as oils, with a few exceptions such as cacao or cocoa butter. Coconut oil, liquid in the tropics, is solid in temperate regions. Storage glycerides of animals, especially the warm-blooded ones, are generally fats. There is no essential difference between an animal and a vegetable fat or oil.

THE FOOD VALUE OF OILS

As oils contain little oxygen, they are highly concentrated reserves of energy. Most plant oils are edible if suitably prepared, though some are rarely so used. Edibility is often a matter of opinion and custom; some oils much prized in certain parts of the world are in no demand in the United States. Some oils are unpalatable; others, particularly the group from the Euphorbiaceæ, of which castor oil is an extremely mild type, contain irritant substances.

DRYING AND NON-DRYING OILS

A more or less distinct oil group, typified by linseed oil, oxidizes in the atmosphere to a tough, resistant film. Although the change is not a dehydration, such oils are known as drying oils. Cotton-seed and many other oils merely form a greasy mass and become rancid on exposure; they are called non-drying oils. Some oils are of a median type.

LOCATION OF OILS

Oily substances are of quite wide distribution in plant tissue but with a very few exceptions, such as olive oil, fixed vegetable oils of importance are derived from endosperm or cotyledon reserves. Oil-yielding seeds, as a group, are known as oil-seeds; they contain, in addition to oil, much protein, but they are usually low in carbohydrate. Oils, as they occur in seeds, are usually mixtures rather than pure chemical individuals; presence of very small quantities of other plant substances may make decided differences in flavor, odor, quality, and utility.

Methods of Obtaining Fixed Oils

Fixed oils may be obtained by mechanical pressure; by heat; by extraction with solvents, such as carbon disulphide, petroleum fractions, and trichlorethylene; or by combination of methods. Pressure, with or without heat, is the most common procedure. It is desirable that the pressure be applied gradually but with great force. Most presses are of the hydraulic or expeller type. The hydraulic press (Fig. 260) is essentially a chamber with a rigid top, whose floor is raised through hydraulic pressure. Materials in a hydraulic press are usually placed in sacks or wrapped in strong coarse cloth which retains the powdery residue as the oil strains through. Expeller presses (Fig. 267) are built on the principle of the household meat-grinder; oil is forced out of the mass by a long revolving screw.

If the material being pressed is heated, oil is rendered more labile and larger yield is obtained. Heating, however, may injure quality; there are often considerable price and use-differences between cold-pressed and hot-pressed oils of the same plant.

As it comes from presses, oil contains water, vegetable impurities, and dirt. From these it is freed by settling and by chemical treatment or refining if necessary.

The vegetable residue or press cake is rich in protein and, except when containing some poisonous substance as in case of castor oil cake, it may be valuable feedstuff. Press-cakes are also ground and used as nitrogenous fertilizer.

Save in case of linseed oil and a few others, solvent extraction is unimportant.

The General Uses of Oils

Food uses have already been mentioned. Utilization is in lard compounds and substitutes, in oleomargarines and butter substitutes, and in salad dressings and salad preparations. Non-food uses are in soaps, in paints and varnishes, and in various specialties. Some oils, as castor oils, are used in lubricating, but for this purpose the very much changed plant substances derived from petroleum are far more important. In some parts of the world oils and oily substances are burned for heat and light, but here again, in modern usage, they have been supplanted by petroleum and other products.

Lines of use somewhat follow drying or non-drying properties. Related oils are generally more or less interchangeable, and choice of material is likely to be governed by price and usage.

1. THE PRINCIPAL NON-DRYING OILS

Cotton-Seed Oil

This most abundantly produced and widely used of all vegetable oils is one of the by-products of the cotton fiber industry (Chapter VII). Oil production was little developed before 1880.

After the ginning of the cotton the seed is screened from refuse, put through de-lintering machines to remove the short hair, fuzz, or linters, and then hulled, after which the kernels (Fig. 258) are heated and pressed. A cotton-seed press (Fig. 260) resembles a horizontal series of steel boxes without ends; the lowest rests upon a hydraulic piston. Within these boxes the kernels are enveloped in heavy cloths to retain solid matter while allowing the oil to strain through. As the power is applied, the oil flows over the sides of the press and into troughs which conduct it to tanks. Here it is allowed to stand till plant residues settle.

Compared with most other oil-seed, yield is low. Cotton-seed affords about 15 per cent oil, 45 per cent cake and meal, 29 per cent hulls, and 5 per cent linters.

Domestic production of cotton-seed oil is usually between 6,000,000 and 7,000,000 tons per year.

About 80 per cent of American cotton-seed oil is used in lard substitutes. By treatment with hydrogen, in the presence of nickel as a catalyst, the oil becomes a white soft solid much resembling lard. It is thus used alone or in combination with other oils and animal fats.

Cotton-seed oil is also used in salad oils, olemargarines, soaps, and for various technical purposes.

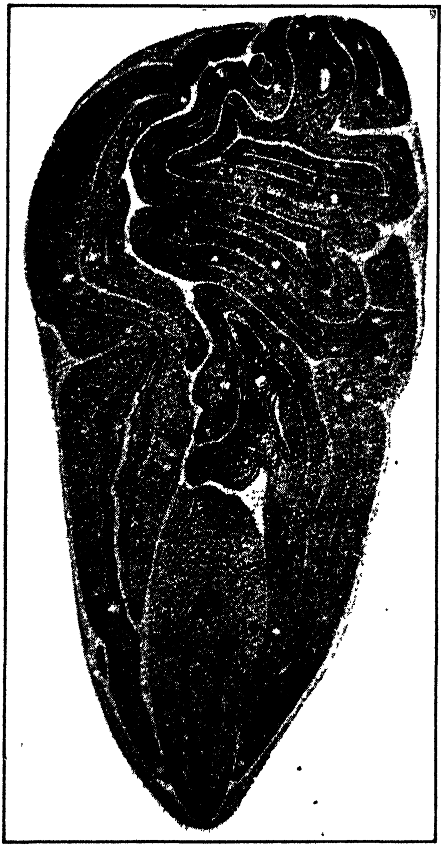

FIG. 258. — Cotton-Seed Kernel in Longitudinal Section, Showing the Radicle and the Intricate Folds of the Cotyledons. The dark dots are glands. (From Stanford and Viehoever, *Journal of Agricultural Research.*)

COTTON-SEED BY-PRODUCTS

Meal from cotton-seed-cake is a most important feedstuff. The dark glands (Figs. 53 and 258) of the uncooked kernels contain a toxic substance, gossypol, but this appears to be altered by heat. The United States Department of Agriculture[1] is author-

[1] United States Department of Agriculture *Yearbook*, 1930, p. 65.

ity for the statement that there is no danger of gossypol poisoning of stock through feeding of the meal. Injurious effects reported from use of cotton-seed meal are in part due to the fact that it is not a complete food, but must be supplemented by other materials.

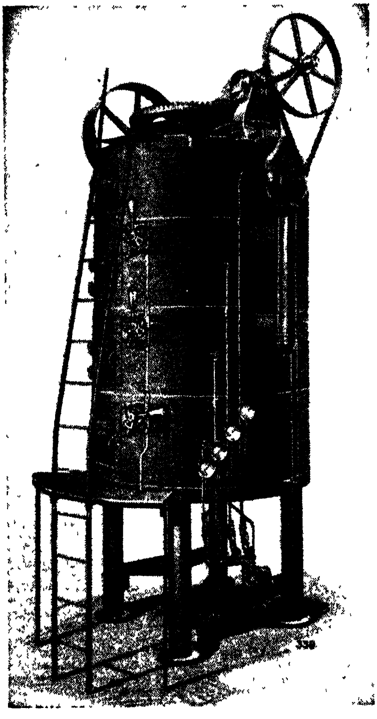
FIG. 259. — A Cooker, in Which Cotton-Seed Kernels Are Heated before They Go to the Press. (Courtesy of The French Oil Mill Machinery Co.)

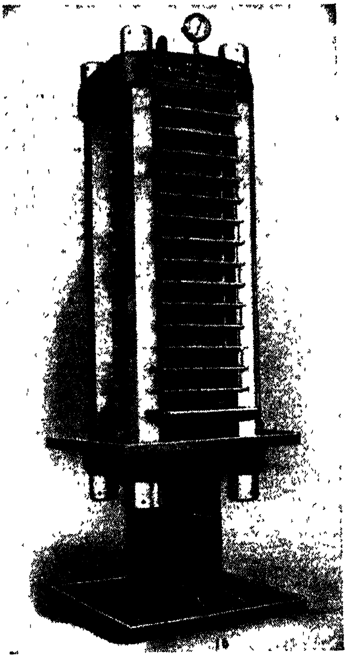
FIG. 260. — A Cotton-Seed Press. (Courtesy of The French Oil Mill Machinery Co.)

Cotton-seed meal is also used extensively as a nitrogenous fertilizer.

Linters removed from the seed find use in rayon manufacture and in coarse fabrics.

WORLD PRODUCTION OF COTTON-SEED OIL

As the United States leads in cotton production, in the utilization of oils, and in the technology of press manufacture and pressing, it is natural that this country should predominate in cotton-seed oil manufacture with probably 75 per cent of the world's manufacture.

About 180,000,000 pounds of oil is pressed annually in Great Britain from Egyptian and Indian seed, and some is manufactured on the Continent and in China. During war-scarcity of fats —and until 1921—the United States exported large volumes of cotton-seed oil, but in more recent years exports have averaged less than 3 per cent of the domestic output.

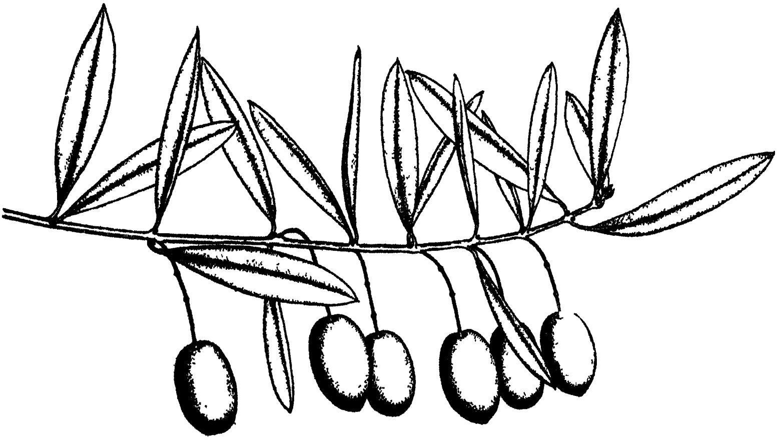

FIG. 261. — Olives. (E. L. Spuller.)

Olive Oil

The Olive (*Olea europaea*) is a small, slow-growing nonhardy evergreen tree of Asia Minor, where it has been cultivated for thousands of years and whence it has spread to Mediterranean Europe. Introduced to new-found continents by early Spanish missionaries, it is now found throughout Latin America. Its growth in the United States is mostly confined to California, where, despite repeated speculative interest, it is far from being a major crop.

The olive flower is small, inconspicuous, and wind-pollinated. The fruit (Fig. 261) is a drupe, usually purplish when ripe; the flesh is bitter and quite inedible without treatment. Olives grown in the United States are mostly consumed without pressing, as preserved ripe olives. Green preserved olives are mainly imported from Spain or Italy.

For oil preparation, olives should be hand-picked when well colored but not overripe. While immediate extraction gives the best oil, the water-content of the fresh fruit renders it rather difficult to handle, and it is usually partially dried before pressing.

As compared with the pressing of cotton-seed, the processing of olives, both in this country and abroad, is a small-scale operation, done in various kinds of small and often primitive mills (Fig. 262) and presses. The details of the processes vary somewhat. The best quality of oil—virgin oil—is made by careful and comparatively light pressure. For a second grade of oil, the pulp is moistened and again pressed. After the second pressing the residue may be treated with hot water and exposed to much higher pressure. The oil thus obtained is known as FOOTS. Foots may also be extracted with solvents, such as carbon bisulphide and trichloroethylene.

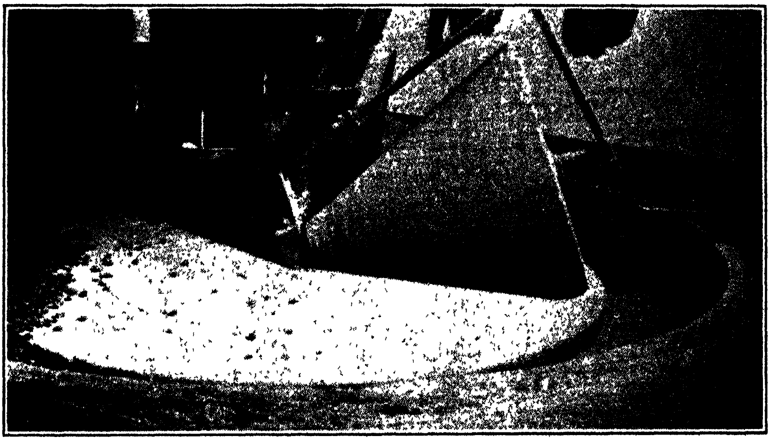

FIG. 262. — A Conical Edge-Runner Olive Oil Mill Used on Farms in Spain. The fruit is fed in from the hopper, the point of which is seen in the upper center; the cone, revolving on a stone or concrete surface, crushes the olives and forces pomace and oil into the circular trough. Oil is separated from the crushed mass in hydraulic presses. The mills are run by mule or ox power. (Courtesy of Division of Viticulture and Fruit Products, University of California.)

Olive oil is the world's most noted edible oil. It owes its prominence in part to long establishment in use, particularly in southern Europe and the Orient. It is one of the blandest of oils, and, when properly prepared, lacks objectionable flavor. Because of its usual high price, interruption of use during the World War, and the recent development of other edible oils, olive oil is losing its place on the American table.

Olive oil is used in the preparation of salads and dressings, often in blend with other and cheaper oils. Quantities are consumed in packing sardines. Technical uses are found in the silk industry and in manufacture of castile and other soaps. Foots and poor grades of oil are used for these purposes.

The Mediterranean Basin is the chief source of olive oil. Spain is the principal producer, but as olive oil in the United States is largely consumed by our considerable Italian-derived population, our imports come chiefly from Italy. California olive oil production normally equals only about 1 per cent of our imports, although larger amounts are pressed when demand for ripe olives slackens.

Fig. 263. — Coconut Palms (*Cocos nucifera*) on the Beach in the Philippines. (Photo from Philippine Bureau of Science.)

Coconut Oil

The Coconut (*Cocos nucifera*) (Fig. 263) is one of the most widespread and useful palms of the tropics, where it occurs both wild and cultivated. The wild acreage would be difficult to calculate; it has been estimated that about 6,250,000 acres are in coconut cultivation. Centers of production are the eastern tropics — the Dutch East Indies, Philippine Islands, various South Sea Islands, Ceylon, and Malaysia. The palm will grow in southern Florida, but there the tree is considered mainly as an ornamental.

The coconut palm is a tall tree of sixty to eighty feet, often more or less crooked or inclined, perhaps from wind-stress upon the huge crown of pinnately compound leaves. The familiar nuts are among the largest of seeds, being borne singly in a thick fibrous husk (Fig. 264). The endosperm is of two portions, the liquid milk in the central cavity and the solid meat, in which a very small embryo is embedded. This meat is the source of copra and of shredded coconut.

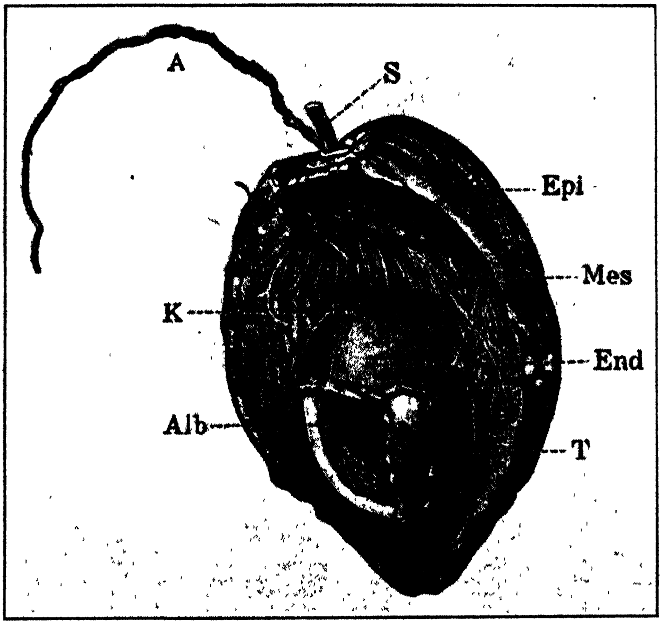

Fig. 264. — Fruit of the Coconut. *A*, branch of axis with scars of staminate flowers; *S*, stem; *Epi*, epicarp; *Mes*, fibrous mesocarp from which coir is derived; *End*, hard endocarp or shell; *T*, inner seed-coat adhering to endosperm; *Alb*, endosperm surrounding cavity of the nut; *K*, eye from which germination takes place. (Reprinted by permission, from *Vegetable Foods*, by A. L. Winton, published by John Wiley & Sons, Inc.)

COPRA

Copra consists of the dried kernel of the coconut. In its preparation the meat is merely broken into pieces and dried by various means. Sun-drying produces the best copra, but in the Philippines and some other humid producing regions rain may interfere. In humid climates copra may be dried on bamboo grates in the smoke of crude furnaces. Drying machines have been devised, but probably not over 5 per cent of the entire copra output is machine-processed.

COCONUT OIL PRODUCTION AND USES

Coconut oil was first produced by natives of coconut-growing regions, by various crude processes. The most primitive method was simply to pound the fresh coconut meat into a pulp, and to allow it to "try out" in the sun in perforated vessels, from which the oil drained. As a later development, copra was dried and crushed in crude stone or wooden presses (Fig. 266). By another method, still in native use, dried pulverized kernels are boiled in water; the oil rises to the surface, and is skimmed off. This boiling process affords a high-grade oil which usually needs no refining.

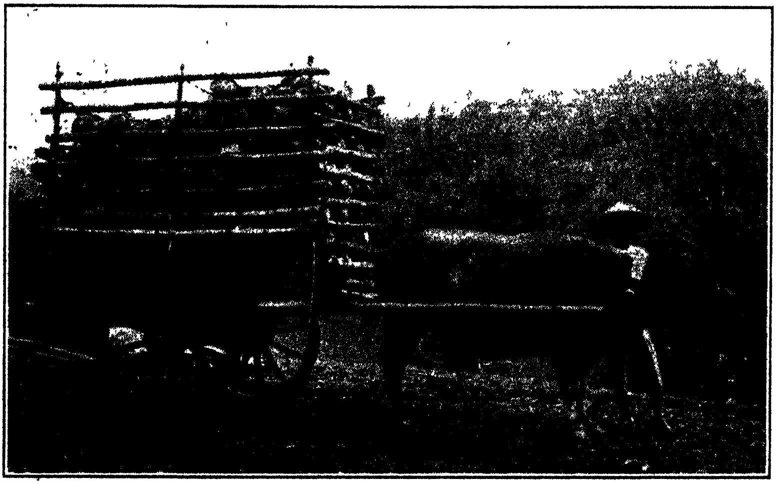

FIG. 265. — Coconuts Going to Market in the Philippines. (Photo from Philippine Bureau of Science.)

Rapidly increasing modern demand for coconut oil has resulted in high development of large-scale pressing. This has been initiated by European and American capital; it is carried on in producing countries and also in the United States and Europe. Cleaned copra is ground, heated, and run through expeller presses (Fig. 267), after which the meal is re-ground, cooked with water, and hydraulically pressed.

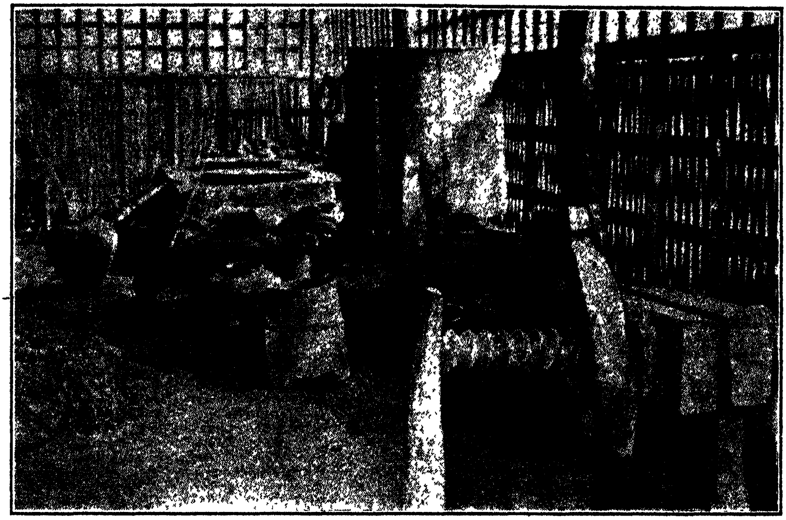

FIG. 266. — A Primitive Philippine Copra Press. (Photo from Philippine Bureau of Science.)

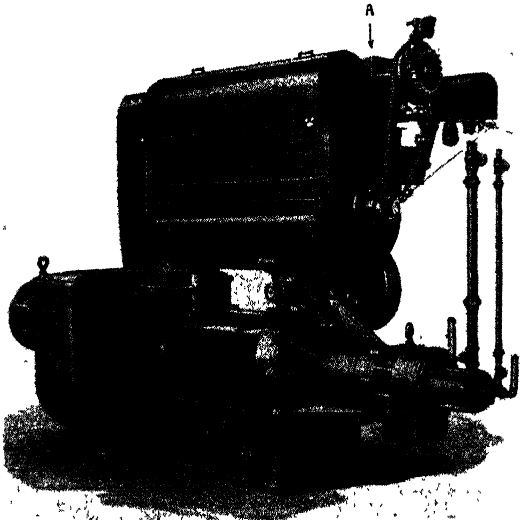

FIG. 267. — Expeller Press Used for Pressing Coconut Oil. *A*, raw material intake; *B*, tempering apparatus, in which moisture content of material is adjusted and heat maintained; *C*, pressing mechanism. (Courtesy V. D. Anderson Co.)

Copra contains on the average about 63 per cent of oil; modern mills recover 95 per cent or more of this.

About 60 per cent of the coconut oil used in the United States is employed in soap-making. Coconut oil soap lathers readily; it is used in making shaving soaps, shampoos, and other free-lathering soaps, and also in those designed for hard and salt waters.

Coconut oil is solid at ordinary temperatures and is therefore especially suited to use in oleomargarines and butter substitutes —a class of products which came into great demand during the World War. Coconut oil butter substitutes are called nut margarines. Quantities of coconut oil are employed in salad dressings, lard substitutes, confectionery, and for various other purposes.

Copra cake is a highly concentrated stock-feed, better known in Europe than in the United States.

WORLD TRADE IN COCONUT PRODUCTS

While fresh coconuts are not an especially important article of trade, some 80,000,000 are imported into the United States annually. About 75 per cent of these are made into shredded coconut, for use in cakes, desserts, and confectionery. Large quantities of shredded coconut are also imported from Ceylon and from the Philippines. Production in the latter islands began about 1922; in 1928 the Philippines furnished two thirds of an import of nearly 62,000,000 pounds.

The Dutch East Indies, Philippine Islands, British Malaya, and Ceylon, in the order named, are the principal exporters of copra; while the United States, Germany, France, and the Netherlands are the major consuming nations. In the export of coconut oil, the Philippines, thanks largely to tariff-protected trade with the United States, are far in the lead.

War and post-war conditions greatly stimulated trade in copra and coconut oil, particularly as concerned the United States and its dependency, the Philippines. In that archipelago the industry has been greatly aided by the free admission of nuts, copra, oil, and shredded coconut to the United States.

Palm and Palm-Kernel Oils

These oils are from the West African Oil-Palm (*Elæis guineensis*). This tree (Fig. 268) is found in vast forests along the west coast of Africa. It is also cultivated there to a limited extent and has been quite extensively introduced in Sumatra.

The pericarp of the fruit (Fig. 269) contains 55–65 per cent of an orange-colored fat, which forms the palm oil of commerce. The endosperm yields palm-kernel oil, which is quite a different product, being white or pale yellow, agreeable in flavor, and resembling coconut oil.

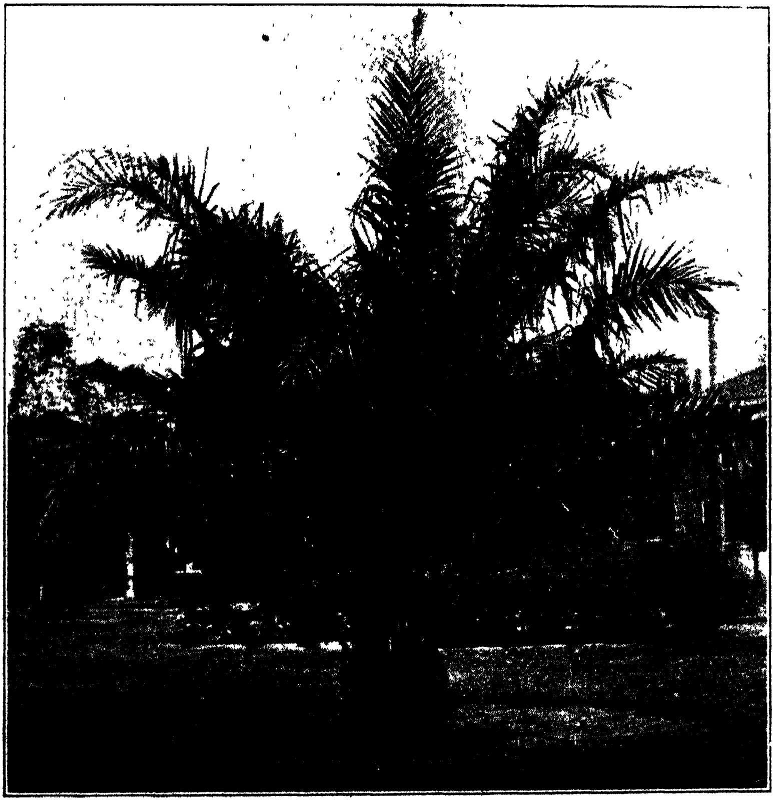

FIG. 268. — A Young Specimen of the West African Oil-Palm (*Elæis guineensis*) Growing in Florida. (Courtesy of Florida Experiment Station.)

The fruit of the oil-palm is an important food of West African natives, who extract palm oil by primitive means involving pounding and boiling the pericarps. The processes are wasteful, and the quality of the oil is usually inferior. A much better product is obtained, by modern methods, in Sumatra. In any case, the kernels are removed and separately processed.

American imports of palm and palm-kernel oil have much increased in recent years and are now close to those of coconut oil.

Palm oil is chiefly employed in soaps. A grease, consisting of palm oil mixed with cotton-seed and mineral oils, is used to prevent rust of the sheet-iron used in tin-plate. Palm oil also finds application in the rubber industry, in textile manufacture, and in various other uses. It can be bleached white, and the better grades are edible.

Palm-kernel oil is a less important commodity. It is used, like coconut oil, in hard-water soaps. Considerable quantities of palm kernels are exported from West Africa to Europe and pressed there.

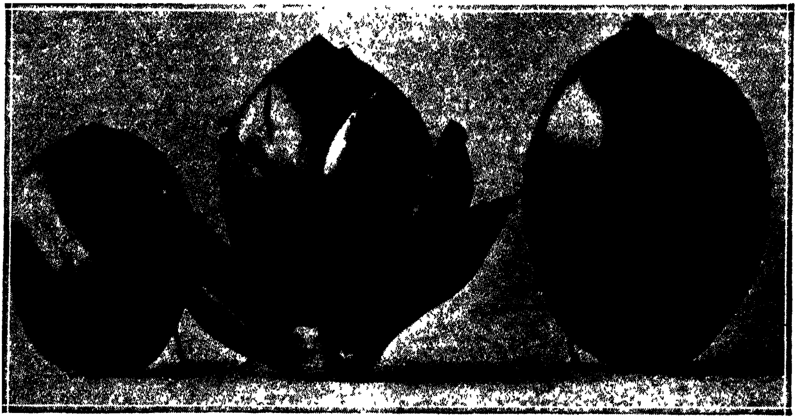

FIG. 269. — Fruits of Three Varieties of the African Oil-Palm. The one in the center is surrounded by a row of aborted carpels from which the oil-yield is very high. (From Fairchild, *Exploring for Plants*. By permission of the Macmillan Company, publishers.)

Castor Oil

Castor oil is expressed from the seeds of *Ricinus communis*, a short-lived perennial tree of India and Africa, now widely grown in sub-tropical and tropical regions. As an ornamental, the castor oil plant is common in American gardens (Fig. 270). Castor seed has been raised as an annual crop in the United States; prior to 1880 it was a minor commercial harvest through a considerable region centering in Kansas. Large cheap supplies from British India presently monopolized the market. Efforts to resuscitate the castor seed crop in the South during the World War met with failure.

The well-known use of castor oil in medicine calls for a relatively small quantity—perhaps 15 per cent—of this oil employed in America. Medicinal oil is of the highest quality and cold-pressed.

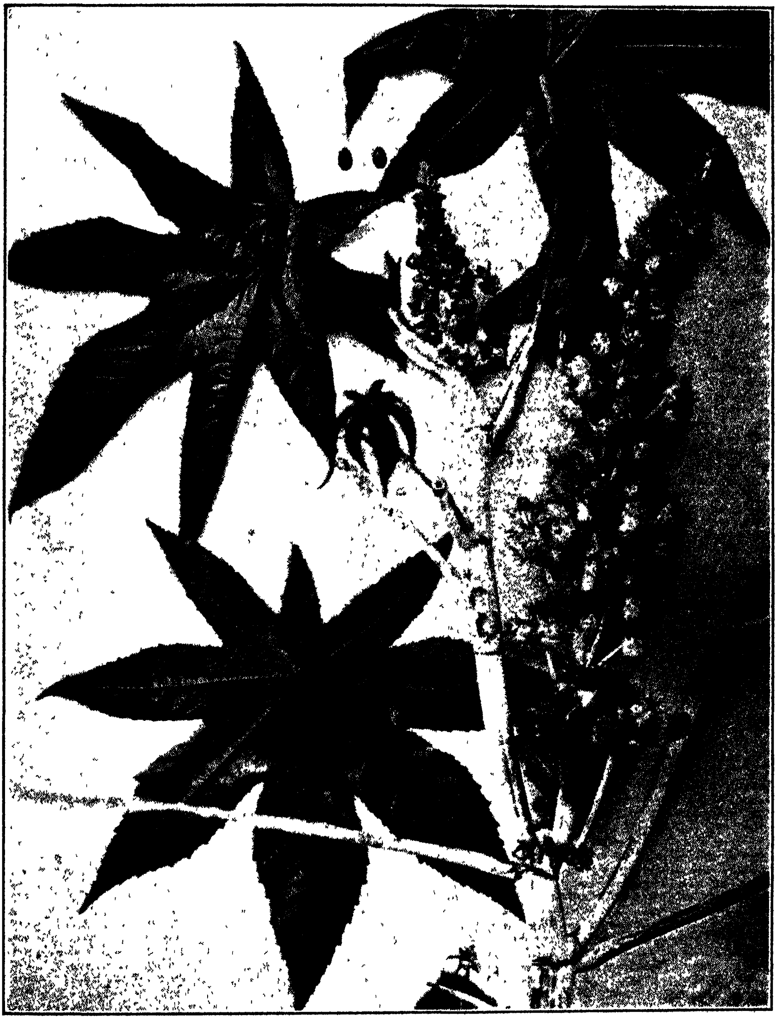

FIG. 270. — Castor Oil Plant (*Ricinus communis*). Staminate panicle above and pistillate at right. Two seeds are shown in upper center. (Courtesy of Bureau of Plant Industry.)

During the World War, castor oil was in great demand as a lubricant for airplane engines, and strenuous efforts were made by combatant nations to increase and conserve the supply. This demand greatly slackened upon cessation of hostilities.

Castor oil is also used in lubricating marine engines and for other lubricating purposes, being blended in some cases with mineral oils.

The principal use of castor oil is in the making of turkey red oil and other alizarin assistants. Alizarin assistants are made by treating oils with sulphuric acid. They are used in dyeing and finishing textiles and to some extent in finishing leather.

Castor oil is somewhat employed in transparent soaps.

Castor press-cake is poisonous and is used only in mixed fertilizers.

Castor seed is chiefly raised in India, whose average output is about 250,000 to 300,000 tons. About 80 per cent of American imports are from India. Brazil supplies some castor seed, and cultivation in China and Japan developed during the World War.

Castor seed is crushed in India but little oil is exported. The United States and other manufacturing nations express most of their own oil from Oriental seed.

2. The Principal Drying Oils

The principal drying oils are linseed oil and Chinese wood or tung oil.

Linseed Oil

The flax plant (*Linum usitatissimum*) is discussed in Chapter VII. As there noted, seed flax is a bushy strain, produced chiefly in regions of short-growing seasons of intense sunlight. The Dakotas and Minnesota are the chief flax-growing States.

Flaxseed (Fig. 272*c*) contains about 33 per cent of oil. The seed is usually hot-crushed in hydraulics with a pressure of about 3,600 pounds per square inch. It may be also cold-pressed, either in hydraulic or expeller presses. Extraction methods, with hot light petroleum as solvent, are also practised. Linseed oil is refined by treatment with sulphuric acid. It is used either raw or boiled. In the production of boiled oil, dryers such as lead and manganese oxides are dissolved in it by means of heat, which, however, does not usually reach the boiling-point of the oil. Boiled oil dries more rapidly than raw, but the film is said to be less durable.

About 65 per cent of American linseed oil consumption is in paints and varnishes and about 20 per cent in linoleum and other floor-coverings. The remainder is utilized in oil-cloth, patent leather, imitation leather, putty, printer's and foundry oils, and soft soaps. Foots, a mucilaginous low grade of oil, is chiefly used in soaps.

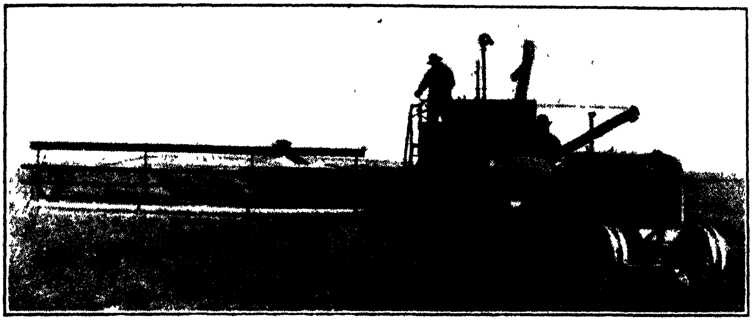

FIG. 271. — Harvesting Flax with a Combine, in Montana. (Photo by M. L. Wilson.)

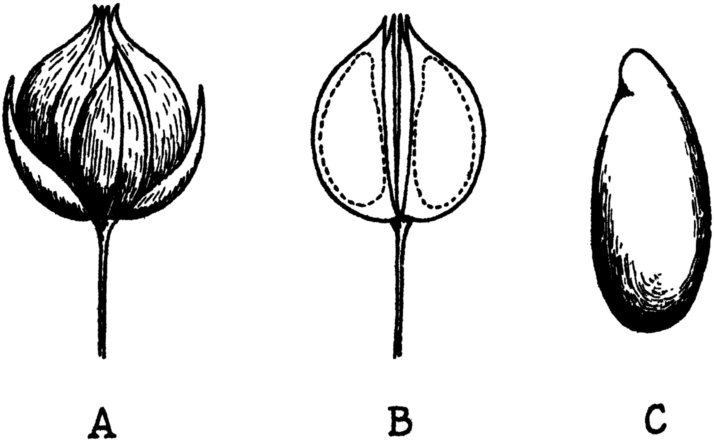

FIG. 272. — Flax (*Linum usitatissimum*); *A*, seed-boll; *B*, same in section; *C*, seed. (E. L. Spuller.)

Hot-pressed linseed cake may be used in stock-feeds, but cold-pressed cake is poisonous.

In times of scarcity and high price, other oils may be substituted—generally in part rather than as a whole—for linseed oil in paint and varnishes. Among substitutes are Chinese nut oil, perilla oil, soy-bean oil, and menhaden oil, the latter obtained from fish.

Flaxseed is a more important article of international trade than is linseed oil, which is generally crushed for domestic use by the large manufacturing countries. Argentina is the largest flaxseed producer, in some years contributing over half the world's supply. Russia, the United States, and India are the other large producers of seed. The United Kingdom and Germany are the largest factors in import and export of oil.

The United States produces about one half its own consumption of flaxseed; its imports come largely from Argentina.

Chinese Nut or Tung Oil

This is obtained from species of *Aleurites* (Fig. 273). Japanese nut oil, from the same genus, is a less important, similar product. Oils of *Aleurites* have valuable drying properties and have largely replaced linseed oil in waterproof varnishes. Imports, chiefly from China, average about 90,000,000 pounds per year.

Experimental planting of tung oil trees has been instituted in Florida and other Southern States, and promising results are reported.

3. OTHER EXPRESSED OILS

Brief Notes on Minor Oils

These are numerous. While some are of considerable food use, or other value, in countries of production, they are, generally speaking, not of major significance in the United States.

SOY-BEAN OIL, extracted from the seeds of *Glycine Max* (see Chapter XII), an important crop in Manchuria, was of considerable importance during the World War, but because of its comparatively high price, its use has since declined. It was employed chiefly in soaps and lard substitutes and—as it is a semi-drying oil—as a partial replacement for linseed oil in paints and varnishes. The highly nitrogenous press-cake is about 50 per cent more valuable than the oil.

PEANUT OIL is an important commodity in France and elsewhere in Europe. At Marseilles in 1924, 400,000,000 pounds were extracted. It is used in salad oils, in margarines, in packing sardines, etc. Like soy-bean oil, its use in the United States declined following the World War.

Corn oil, a by-product of the corn-products industry, is used in cooking.

Rapeseed oil and other expressed oils from various mustards[1] are used as food in India and elsewhere in the Orient. About 75 per cent of American use is in compound lubricating oils for marine and automobile engines. Other uses are for quenching steel plate and as sanctuary oil in churches.

Fig. 273. — Fruit of the Tung Oil Tree (*Aleurites Fordii*). (Courtesy of Bureau of Plant Industry.)

Sesame or benne oil from *Sesamum indicum* (Pedaliaceæ) is one of the staple food oils of India. It is said not to become rancid on exposure and has limited use in salad preparations, soap stock, and pharmaceuticals in the Occident.

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[1] Not to be confused with "oil of mustard," which is a highly acrid volatile product, allyl isosulphocyanide.

HEMPSEED and POPPY SEED oils are minor commodities. The latter is used in the finest qualities of artist's paints. In the Old World it is quite largely used as an edible oil.

EXPRESSED OIL OF ALMONDS [2] also known as sweet almond oil, is a high-priced product used chiefly in pharmacy. Pressed oils of apricot and peach kernels have similar properties and are said to be sometimes mixed with it. Almond press-cake is used in cosmetics and toilet soaps.

PERILLA OIL—from *Perilla ocymoides* of Japan, China, and northern India—is a drying oil, employed in paints, varnishes, linoleum, and printing inks.

CACAO or COCOA BUTTER is a vegetable fat obtained from the cacao bean (*Theobroma Cacao,* see Chapter XV). It is in part a by-product of cocoa and chocolate manufacture. It is used in pharmaceutical preparations and as an aid to mixing sugar and milk into chocolate in the making of confectionery.

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[2] Not to be confused with the highly poisonous oil of bitter almonds, which is a distilled product, containing hydrocyanic acid.

CHAPTER XII

PLANTS AND NITROGEN: PROTEIN PRODUCTS

1. PLANTS AND NITROGEN

The principal nitrogenous foods of mankind in general are proteins of the meats of animals. Meats are not, to be sure, our sole protein foods; our "daily bread" necessarily contains plant nitrogen. Millions in the Orient are vegetarians; and many people elsewhere, whose diet is less restricted by circumstance, prefer to obtain their nitrogen wholly or largely from the plant kingdom. In any event, when we use nitrogen in the metabolism of our bodies we avail ourselves directly or indirectly of the labors of plants; not an atom of that most abundant atmospheric element can enter the animal system without first having been captured and combined in the living laboratories of plant organisms. It is desirable, therefore, first to review the manner in which nitrogen is made available to living things, and then to glance at some plants and plant products which are of particular significance because of their protein content.

The Nitrogen Cycle

The series of changes through which nitrogenous material may pass in organized nature is known as the nitrogen cycle. In Fig. 274 the principal sequences are shown in diagrammatic form.

Nitrogen, which makes up about 80 per cent of the atmosphere, is, in its free form, as unavailable to the higher plant as it is to the animal. Small amounts of it are oxidized by the electric discharges of thunder-storms and washed in rain to the ground. There the oxides react with soil minerals, and nitrates may be formed. Nitrates are the principal form in which nitrogen is absorbed by the roots of green plants; the amount of soil-nitrate which results from electric discharge is, however, inconsiderable and wholly insufficient to supply the tremendous demand of living organisms for nitrogen. In recent years, successful efforts have been made to capture atmospheric nitrogen by chemical processes and to combine it in forms which can be added to the oil to increase fertility. Much of the success of modern efforts to fix atmospheric nitrogen are due to the use of nitrogen compounds in explosives and for other industrial purposes. Details of the processes used will be found in any textbook of elementary chemistry. For 1930, the total production of combined nitrogen from natural nitrate deposits, from various by-products of chemical industries, and from chemical fixation of atmospheric nitrogen, is estimated at about 2,180,000 metric tons; of this amount 58.4 per cent was from atmospheric nitrogen. Amounts of nitrogen thus made available for renewing the nitrogen supply of the soil are, from the farmer's point of view, of great significance in renewing nitrogen supplies in tilled fields. While we have no basis for direct comparison, the amounts manufactured are doubtless but the proverbial "drop in the bucket" as compared with the nitrogen requirements of organized nature, which have been met, probably since life first began, mainly through the activities of bacteria in the soil.

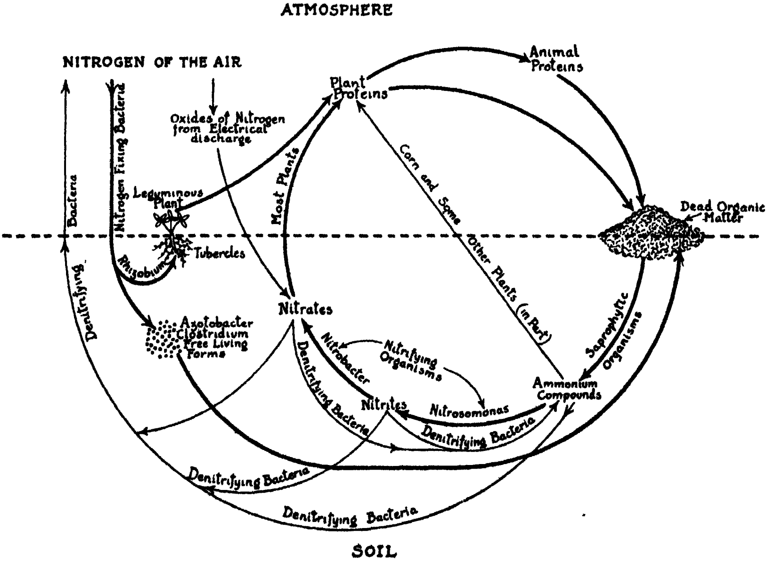

FIG. 274. — A Diagrammatic Representation of the Nitrogen Cycle.

BACTERIA AND NITROGEN FIXATION

Several types of bacteria are involved in the capture of atmospheric nitrogen. Some live free in the soil; others carry on their activities within the roots of higher plants.

Free-living bacteria which fix nitrogen.—One of the most striking of these forms is known as *Azotobacter* (Fig. 275). *Azotobacter* is a comparatively large bacterium which carries on a most complicated life-cycle in the soil. Its source of energy is mainly carbohydrates; by rapid respiration of these some of the energy released is utilized to fix or combine atmospheric nitrogen within the protoplasm of *Azotobacter*. The compounds of nitrogen thus formed are eventually released in the soil, and there re-worked by saprophytic organisms and by the nitrifying bacteria presently to be noted. Another bacterial form, *Clostridium*, likewise carries on nitrogen fixation in the soil. In artificial culture, *Clostridium* fails to grow in the presence of free oxygen. In the soil, presumably, the activities of other organisms in some way shield *Clostridium* against the unfavorable effects of free oxygen. There are many details of the life of nitrogen-fixing organisms which, despite a vast amount of study, are still obscure.

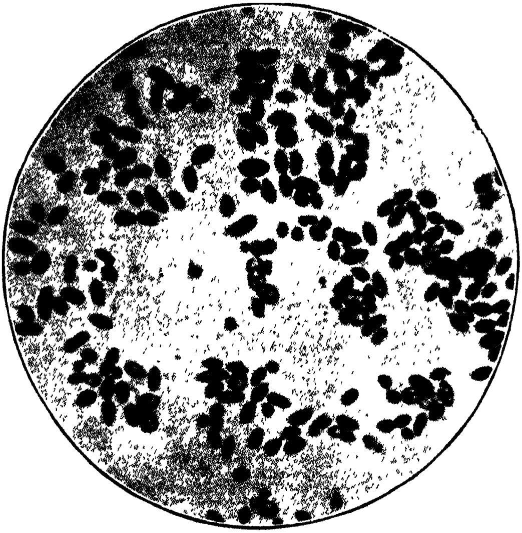

FIG. 275. — Azotobacter, a Free-Living Nitrogen-Fixing Microörganism. (Courtesy of Bureau of Chemistry and Soils, United States Department of Agriculture.)

Rhizobium.—Bacteria of this genus carry on a sort of beneficent parasitism within the roots of plants of the great family Leguminosæ. In their tissues *Rhizobium* forms nodules or tubercles (Fig. 276), which are masses of hypertrophied tissue whose cells are crowded with the living bacteria. These bacteria fix free nitrogen, which eventually is used by the leguminous host, in whose composition it appears in protein form. The leguminous plant may be eaten by an animal, in which case the protein it utilized or stored; the dejecta from the animal and eventually the animal itself, return to that great store-house of dead organic matter in the soil. If the plant dies without being eaten the soil return is the more rapid.

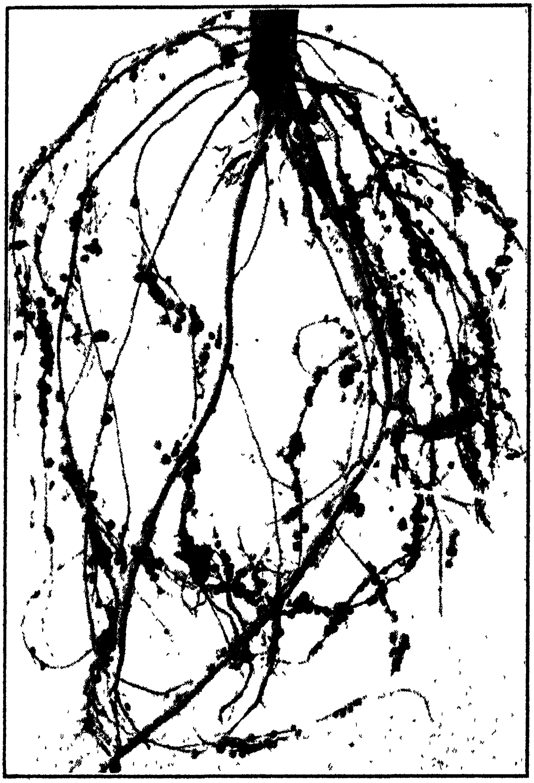

FIG. 276. — Bacterial Tubercles or Nodules of a Leguminous Plant, the Soy-Bean (*Glycine Max*). (Courtesy Bureau of Plant Industry.)

BACTERIAL DECOMPOSITION OF PROTEINS AND ITS CONSEQUENCES

Decomposition of plant or animal bodies in the soil.—Soil, essentially, is a mass of more or less decomposed rock debris, with variable water and air content. Soil almost invariably contains also the remains of dead organisms, and these remains support the life and activities of myriads of bacteria. Many of these soil forms reduce proteins, which eventually appear as ammonia or ammonium compounds. Corn and some other plants make some direct use of ammonium compounds, but the majority of green organisms utilize nitrates.

Nitrification.—The change from ammonium nitrogen to nitrate nitrogen commonly takes place in two steps, both due to soil bacteria. A form known as *Nitrosomonas* carries on a partial oxidation, and nitrites result. Another organism, *Nitrobacter,* forms nitrates from nitrites and does it so efficiently that tests for nitrite in the soil generally give negative results. The root-hairs of plants take the nitrates in solution from soil water. Proteins are re-formed, again to go through the steps of animal use or direct decomposition by saprophytes.

Denitrification.—Certain types of soil bacteria possess the capacity to utilize nitrogenous matter in various ways of which the eventual result is reduction to free nitrogen. These changes sometimes go on in water-logged soils and may result in considerable loss of fertility.

2. PLANTS WHICH YIELD NITROGEN

Of all plants which afford protein to man and animals, those of the Leguminosæ stand first in general significance. The family is an enormous one, with 12,000 or more species widely distributed throughout the world. Long ago, before the microscope had revealed the first bacteria ever seen by man, it was known that the culture of such plants as the clovers and the beans and the peas increased the fertility of the soil and made possible larger yields of other crops in future years. Before the word PROTEIN had a meaning in any language, men had discovered that peas, beans, and other large seeds of what we now call the legume crops were highly concentrated capsules of nourishment. While the seeds of the cereals may rank first in immediate foodstuff use, the Gramineæ deplete the soil and return to it none of that essential element, nitrogen, save that which they found there as a result of decomposition from other sources. If the legumes themselves do not catch nitrogen, they make it possible for other organisms to do so. If one had to assign first rank to any plant group—a rather futile task—it would be hard to deny the honor to the Leguminosæ.

Outside this family, many plants yield foods rich in protein. The presence of protoplasm, in fact, connotes the presence of protein. But the majority of edible plant parts and many storage regions, such as underground stems and roots, are very low in nitrogen as compared with meats and with the seeds of beans and peas. Plant foods of notable protein concentration are almost wholly drawn from seeds. Those of the cereals generally contain from 8 to 12 per cent of protein. Seeds which are notably rich in protein usually contain considerable amounts of oil. The commercial oil-seeds are high in protein; so, too, are nearly all the so-called nuts. Save for their usual high cost, most of the nuts would be valuable oil-sources.

Proteins from various sources differ somewhat in digestibility and biological efficiency. Also, there are some plant products rich in nitrogen which are rendered valueless for food use by the presence of poisonous or unpalatable components, such as the highly toxic ricin of the castor oil seed, one of the most poisonous substances in the entire vegetable kingdom.

The Leguminosæ

The Leguminosæ are plants of diverse habits. The group includes trees, shrubs, vines, and herbs of all periods of duration. Legumes of foodstuff and feedstuff value are nearly all annuals or herbaceous perennials; occasional crop plants, like the sweet clover, are biennial. The root systems are generally of the taproot order, with numerous branches. Those of alfalfa and other perennials often penetrate deeply. Entry of tubercle-forming bacteria takes place on the younger portions of roots; nodules are discernible on very young seedlings. If no suitable *Rhizobium* forms are present in the soil, the plants fail to thrive. Artificial soil or seed inoculation with specially prepared bacterial cultures is a common procedure; the same result may often be attained by plowing in soil from fields in which the particular leguminous plant has been grown. A strain of *Rhizobium* which will infect one legume may fail to enter another species.

The most valuable forage-crop and hay legumes are plants of quick-growing habit, whose above-ground parts are profuse but little woody, readily eaten by animals or incorporated in the soil.

The leaves are almost invariably compounded on the pinnate plan, with three or more leaflets. Leaves are frequently much richer in nitrogen than the stems.

The flowers of the most characteristic legumes are of that type called papilionaceous (Fig. 277); the term is derived from *papilio*—butterfly—and refers to the fancied resemblance of the blossom to that insect. Those of the Sweet Pea (*Lathyrus*) and of many other genera are of striking beauty. The calyx is of more or less united sepals, which often remain in position though somewhat withered while the fruit ripens. The corolla is of five petals—a large more or less upright banner, two lateral wings, and two petals united by their lower edges into the keel. The keel encloses stamens and pistils. Stamens are ten; in many genera the filaments of nine of these are united in a sheathlike structure about the pistil, while the tenth lies free above it. The pistil commonly has a flattened ovary, with several seeds; it ripens into a legume, or pod, of which those of the bean and pea are good examples.

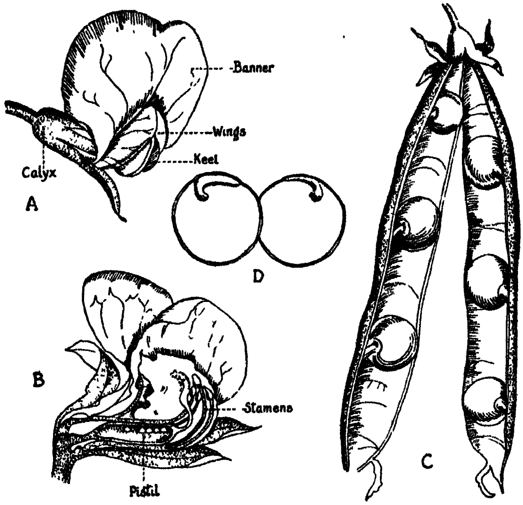

FIG. 277. — Flower and Fruit of the Pea (*Pisum sativum*). *A*, outer view; *B*, view in median longitudinal section, after Engleder; *C*, legume or pod, showing dehiscence and seeds in place; *D*, seed, opened, showing the two large cotyledons and the hypocotyl and plumule (above). (E. Coffman.)

Seeds of the legumes possess two thick cotyledons (Fig. 278) which are abundantly stored with protein, and often also with oil or starch. The remainder of the embryo is comparatively small; endosperm is almost or quite lacking from the mature seed.

Human dietary use of the legumes is chiefly confined to the seed. These must be large, abundantly produced, and palatable; ready shelling quality and lack of dense, shell-like seed coats is also desirable. Some legumes, such as the Loco Weeds (*Astragalus* spp.), and some lupines fail of use and value because of poisonous constituents.

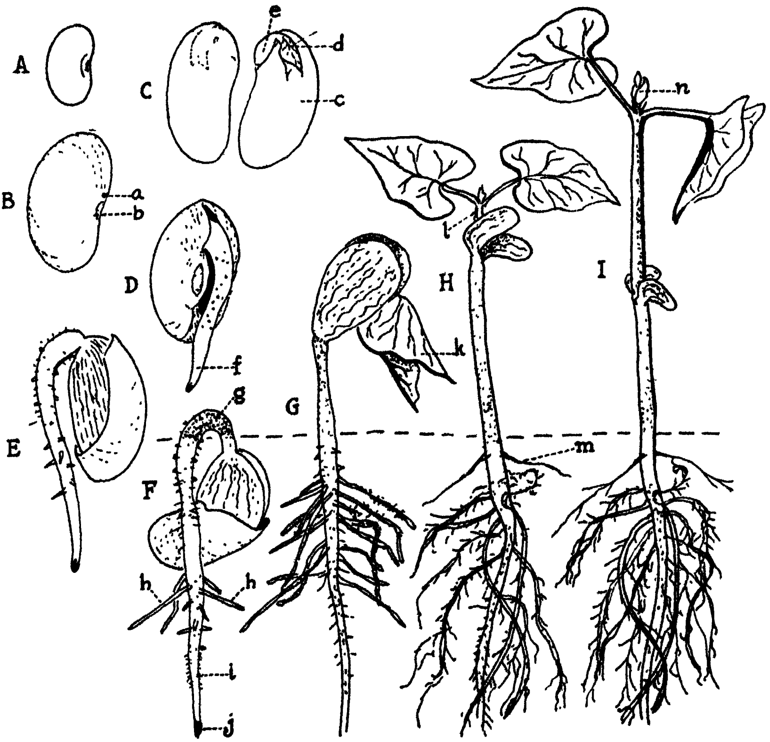

FIG. 278. — Stages in the Germination of a Leguminous Seed, that of the Bean (*Phaseolus*). *A*, dry seed; *B*, seed expanded by absorption of moisture (*a*, micropyle; *b*, hilum); *C*, seed with seed-coats removed (*c*, cotyledon; *d*, plumule; *e*, hypocotyl); *D–E*, early germination stages (*f*, radicle); *F–I*, later stages, the soil-level shown by the dotted line (*g*, arch of the hypocotyl, the lower portion of the caulicle; *h*, lateral roots; *i*, root-hairs; *j*, root cap; *k*, first foliage leaves formed by expansion of those of the plumule; *l*, epicotyl; *m*, adventitious roots; *n*, bud from which further growth proceeds). (H. McCarthy.)

In so far as it is possible to effect separation upon the basis of predominent use, the Common Bean and the Lima Bean (*Phaseolus* spp.), the Pea (*Pisum*), the Peanut (*Arachis*), and the Soy-bean (*Glycine*) are chiefly food products; Alfalfa

(*Medicago*), Clover (*Trifolium*), the Cowpea (*Vigna*), and Vetch (*Vicia*) are important as forage plants, hay crops, and for soiling (soil improvement) use. Many other genera might be mentioned in each category.

Feed, Forage, and Soiling Crops

ALFALFA

Medicago sativa (Alfalfa or Lucerne) is probably native to Persia and Asia Minor. It was cultivated by the Romans, and has long been an important crop in Mediterranean Europe. Its major importance in the United States dates from the settlement of the region west of the Mississippi. A survey by the United States Department of Agriculture some years ago placed 86½ per cent of the crop west of the Ninety-fifth Meridian.

Alfalfa (Fig. 279) is a deeply rooted, many-stemmed perennial, with a cropping life of five to seven years—a period which is often exceeded in semi-arid regions. The tap root, under exceptional conditions, has penetrated the soil to a depth of twenty-five to thirty feet; alfalfa, once established, is very drought resistant. It thrives best in a dry atmosphere; in a humid climate it may succumb to diseases or be crowded out by weeds.

From numerous buds—on a short, erect crown or stem at or just below the soil surface—proceed numerous slender stems, two to three feet high. The abundant leaves are trifoliate. The flowers, in rather dense spikelike racemes, are usually blue or purple. The ovary is bladelike in the blossom, but on ripening becomes a short, tight spiral. The small, hard seeds are remarkably long-lived; experiments have shown little loss of viability in twenty years under reasonably good storage conditions. Because of the slowness with which water penetrates the seed-coats, it has been found profitable to scarify alfalfa seed by mechanical treatment before planting.

Alfalfa is generally cut for hay just before flowering and cured slowly so that the leaves, which may contain 80 per cent of the protein of the herbage, are not crumbled or shattered. Three or more crops can be obtained in a season.

Alfalfa is the leading hay legume of the United States and has been termed the world's greatest forage crop. Its values lie in its perennial nature, its cropping qualities, its palatability to stock, its high nitrogen and mineral content, its drought resistance, and a fair degree of hardiness. Alfalfa hay yields 11.5 per cent protein, as against 8.3 per cent for timothy. Like other legumes, it has its place in the nitrogen cycle and is used in rotations and soil-improvement plans.

Although alfalfa is mostly consumed in the growing regions, considerable amounts are baled and shipped. The grinding of alfalfa meal, for use in mixed feeds, is an important industry in some places.

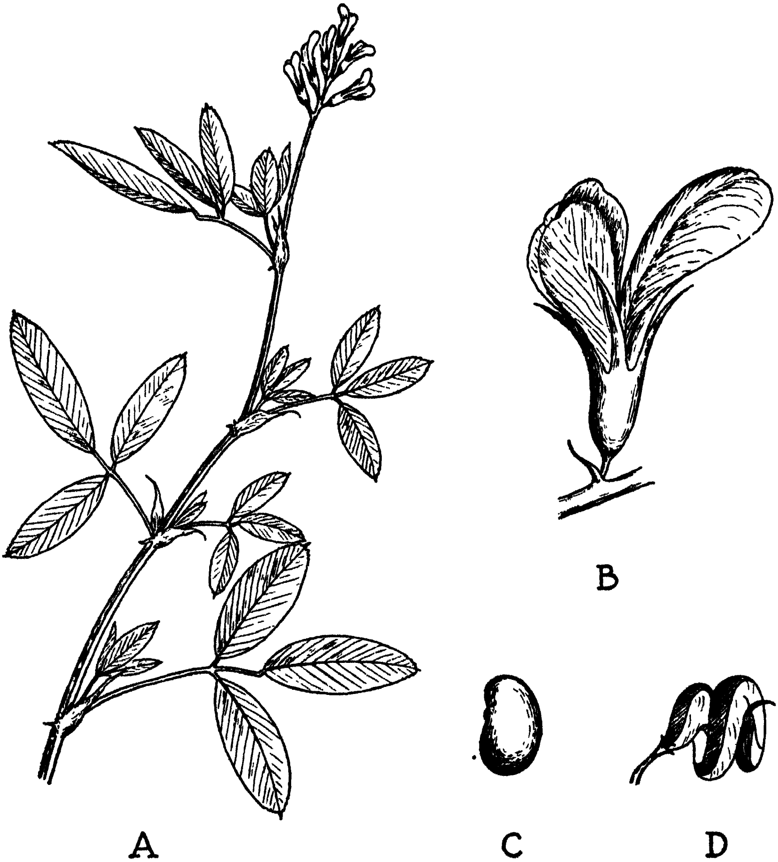

FIG. 279. — Alfalfa (*Medicago sativa*). *A*, leaves and inflorescence; *B*, flower; *C*, seed; *D*, fruit. (E. L. Spuller.)

Alfalfa is the leading honey plant of California and is valued for bee-pasturage throughout its range.

The raising of alfalfa seed is an important industry in several

States; Kansas and Montana lead in quantity. The crop of 1930 was 1,165,600 bushels; that of the two succeeding years, considerably less.

THE TRUE CLOVERS

The term CLOVER, with definitive, is used for several groups of legumes. Bur Clovers are species of *Medicago*; Sweet Clover, of *Melilotus*; Japan Clover, of *Lespedeza*. CLOVER, when used alone, belongs properly to the genus *Trifolium* (Fig. 280), a widespread herbaceous group of some 300 species. Nearly all are palmately trifoliate; the flowers of most of them are small and borne in dense headlike masses. Many clovers are native to the Rocky Mountain region and the Pacific Coast States, but the half dozen of principal agricultural importance are European or Eura-

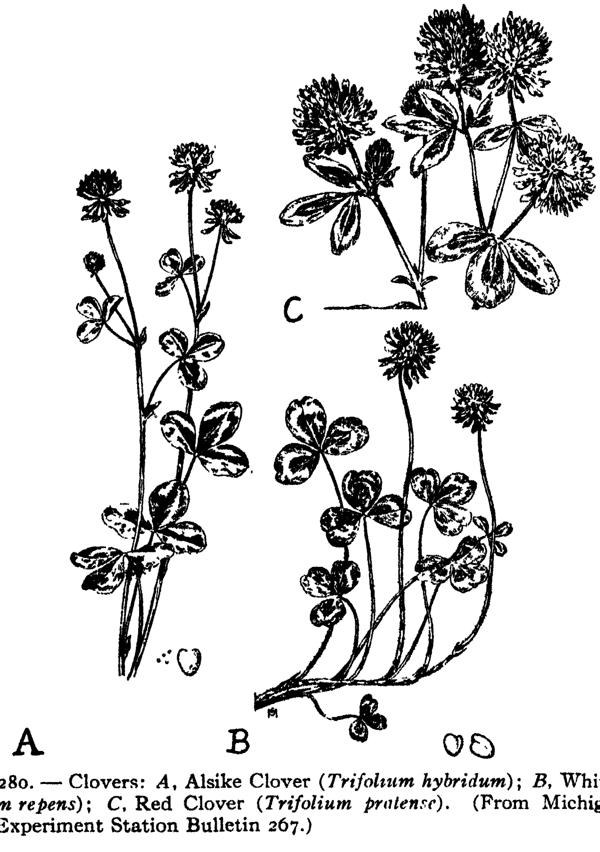

FIG. 280. — Clovers: *A*, Alsike Clover (*Trifolium hybridum*); *B*, White Clover (*Trifolium repens*); *C*, Red Clover (*Trifolium pratense*). (From Michigan Agricultural Experiment Station Bulletin 267.)

sian. All of these are perennial save one, crimson clover. Clovers, unlike the principal legumes grown for human food, are not of ancient cultivation; their importance in soil improvement and for hay and forage crops remained to be realized in the last two centuries.

While alfalfa is the principal hay legume of the West, the clovers dominate the more humid northeastern sector of the United States. The western boundaries of Minnesota, Iowa, and Missouri, and the northern lines of Arkansas, Tennessee, and North Carolina enclose the principal clover areas. Here also is the principal range of timothy. While alfalfa is commonly grown as a sole crop, clovers are likely to be mixed with timothy, other grasses, or oats, and to be grown in short terms and rotations with other crops.

The principal large-crop hay clovers are red clover and alsike clover. Several years ago the United States Department of Agriculture estimated that in the main clover region about 65 per cent of the crop was red clover and 30 per cent alsike.

Red Clover.—*Trifolium pratense,* Red Clover (Fig. 280*C*), is a vigorously growing, somewhat hairy perennial with dense heads of pinkish red or purplish red flowers.

It is the most conspicuous of the commonly naturalized clovers and is well established in the main clover region and occasionally elsewhere. It is rather short-lived and tends to be crowded out of dominance in lands that are not frequently re-seeded. Red clover does not thrive in a dry atmosphere or in poorly drained or shaded soil. While it has excellent nutritive values, the masses of flowers sometimes cause intestinal obstructions in animals.

The flowers of red clover are long-tubular and commonly pollinated by bumblebees, whose "tongues" are longer than those of honey-bees. It has been claimed that honey-bees are unable to plumb their depths, but it would appear that under some circumstances they can extract nectar from them. Red clover, at all events, is not counted an important honey-plant.

Production of alsike and red clover seed (Fig. 281) covers about 1,000,000 acres annually, this being twice or thrice the space devoted to alfalfa seed raising. The annual crop is in the neighborhood of 1,500,000 bushels; amounts and acreages of the two clovers are not separately available.

Alsike Clover.—While red clover has long been an agricultural standby in the United States, Alsike Clover (*Trifolium hybridum*) (Fig. 280*A*) is of more recent popularity. Alsike was once thought to be a hybrid between white and red clovers. It is now considered a good species; the name *hybridum* is therefore a misnomer. It is a vigorous, much-branched perennial, with pale pink flower-heads. It is hardier than red clover and can be grown on acid, wet, and occasionally overflowed lands where *Trifolium pratense* does not thrive. Like red clover, it is generally planted with timothy or other grasses. Alsike, red clover, and timothy are a popular mixture. Alsike is said to maintain itself better in pastures than does red clover.

Crimson Clover.—Italian or Crimson Clover (*Trifolium incarnatum*) is a large annual species with bright crimson or sometimes white elongated heads. It is less hardy than the other cultivated clovers and is mostly grown in the South. It is a more tolerant of shade than red or alsike clovers and is often grown in orchards. Even more than those of red clover, its heads are apt to form intestinal obstructions in horses.

White Clover. — White Clover (*Trifolium repens*) (Fig. 280*B*) is a small mat-like perennial with long-stemmed white heads. It is widely naturalized throughout the United States. While rarely planted alone, it is the most common clover of lawns and lawn-grass mixtures, a use to which its tenacious, creeping, slender-stemmed habit particularly adapts it. In meadows it is not conspicuous, being overtopped by tall grasses and the larger clovers; which often hide its real abundance. It is common in old fields and along waysides. Of all the clovers, white clover is most prized for honey production. Lacking white clover, Eastern bee-keeping would be a precarious pastime. Not only is the nectar abundant, but it is of remarkably high quality.

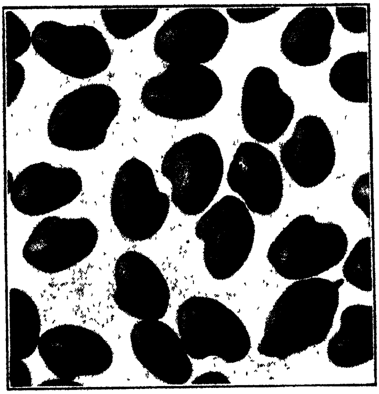

FIG. 281. — Seed of Red Clover (*Trifolium pratense*) Enlarged. (Courtesy of Bureau of Plant Industry.)

A vigorously growing race of white clover known as Ladino Clover is becoming popular for hog forage in the Pacific States.

Other clovers occasionally cultivated are *Trifolium alexandrinum,* Berseem or Egyptian Clover, and *T. medium,* Zig-zag or Cow Clover.

SWEET CLOVER

Melilotus alba, White Sweet Clover, is a sparsely branched vigorously growing biennial or annual with long slender racemes of white flowers. The name SWEET CLOVER comes from the fragrance of the herbage. Sweet clover somewhat resembles alfalfa in habit, but is less leafy; the foliage has a bitter character and stock have to acquire a taste for it. The plant readily becomes established along roadsides and waste places and does well in many regions where alfalfa does not thrive. When first introduced, it was generally regarded as a weed, but in the period since 1920 it has become very popular in some localities, particularly in the Corn Belt and in the Northwestern States. It is highly regarded for qualities of soil improvement and is much used in rotations and in mixtures with small grains for hay and forage. Use of second-year sweet clover hay has sometimes been followed by outbreaks of a disease among young cattle in which the clotting power of the blood is diminished; affected animals may bleed to death from minor wounds or from internal hemorrhage. The disease does not appear to be caused by the first-year crop of hay.

Sweet clover yields excellent honey and is an important source of nectar.

Two species of yellow sweet clover are occasionally grown.

THE COWPEA

The Cowpea (*Vigna sinensis*) is a bushy or trailing annual from Asia, which has made a secure place for itself in the agricultural economy of the Southern States. In seeds and habit of growth (Fig. 282) it much resembles the beans. It does not thrive in cool climates and is rarely seen in the North. It is the principal legume grown in the South for soil improvement and for pasturage; here, also, the seeds (Fig. 283*I*) are an important article of diet among the poorer classes.

THE VETCHES

Vetches are species of *Vicia*. The genus has about 100 members, of which two, Common Vetch (*V. sativa*) and Hairy or Hungarian Vetch (*V. villosa*) are considerably grown for soil improvement and hay production. These are sprawling, herbaceous vines, with several-pinnate compound leaves whose terminal leaflets are modified into branching tendrils. The flowers of common vetch are borne in ones and twos; those of hairy vetch in one-sided racemes of twenty or thirty blooms. Seeds of these species are small and hard (Fig. 293*E*).

Vetches are popular for mixed growth with timothy. They are extensively grown in the Pacific Northwest and are thoroughly naturalized in Oregon and Washington. The Willamette Valley of Oregon is an important center of vetch seed production.

Related to the vetches is the Broad Bean (*Vicia Faba*) otherwise known as the Windsor Bean and Horse Bean. The broad bean is a stocky erect annual. There are many varieties, differing considerably in size and character of seed (Fig. 283*A*). The characteristic broad bean has the largest seeds of the common legumes. It has been used for human food since prehistoric time

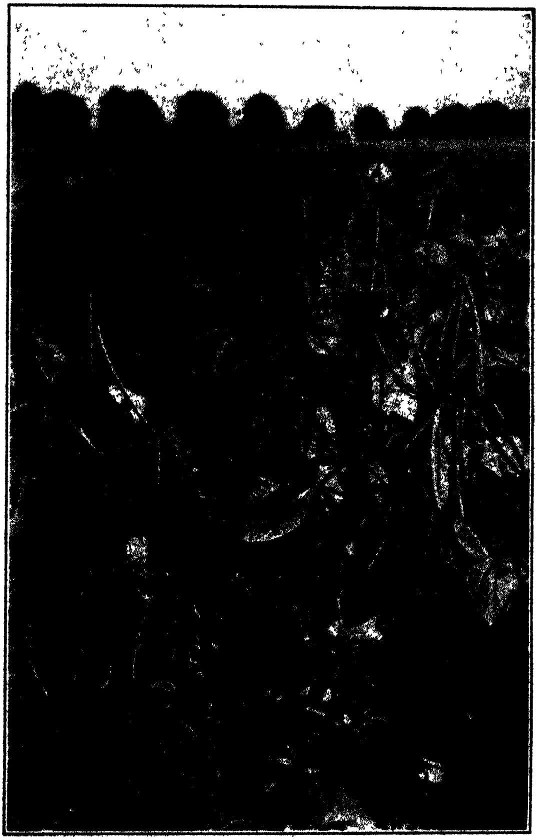

FIG. 282. — The Cowpea (*Vigna sinensis*). (Courtesy of the Bureau of Plant Industry.)

but has never become popular in the United States. It is, typically, a cool climate plant and is considerably grown in Canada. Small varieties—horse beans—are grown to some extent as soil-replenishing and cover crops in California.

Crops of Food Significance

THE BEANS

The principal beans used in North America for human food are the Common Bean (*Phaseolus vulgaris*) and the Lima Bean (*P. lunatus*). In the Orient the Soy-bean (*Glycine* or *Soja Max*) is dominant. The "bean" of the ancients seems to have been the Broad Bean.

The Common Bean.—*Phaseolus vulgaris* appears to be a native of the New World. The plants are annual, with considerable variation of habit. The majority of the many varieties of field beans, including those grown on a large scale, are bush beans; other kinds have twining habits and are grown on poles. The leaves are pinnately trifoliate. Flowers are white or tinged with yellow or purple. Seeds vary greatly in size, color, and markings (Fig. 283*C*). Pods of many varieties are edible when young, and are utilized as SNAP BEANS. Kinds with little or no chlorophyll are known, from their appearance, as WAX BEANS.

Beans are very frost-sensitive, but most varieties require only a short growing season and are adapted to a wide range of climatic and soil conditions—factors which have spread them widely over the agricultural globe.

Beans have been important in the native diets of South America and Mexico since prehistoric time. After the discovery of America, the bean rapidly attained wide distribution in Europe and in the Orient. The popularity of the bean is due in large part to the high food value of the seed and to the ease with which it can be transported and kept. If insects and moisture be avoided, dried beans, like the cereals, may be preserved indefinitely. As foodstuffs, beans are extensively used—though not always popular—in armies and navies and in institutions such as jails, asylums, and the like, where considerable numbers of people must be fed at minimum expense.

The principal commercial beans grown in the United States are small white kinds, called pea beans, navy beans, etc. Red kidney varieties are also popular. Pinto and pink beans are raised in the Southwest, being extensively used by the Indian and Mexican population. Besides *P. vulgaris*, varieties of the Scarlet

Runner (*P. multiflorus* or *P. coccineus*) and some other members of the genus are grown in that part of the country and to some extent elsewhere.

A large proportion of the white bean crop is used in canned baked beans and other canned forms.

In quantity of output, the bean canning industry is the largest of its kind, the annual pack somewhat exceeding that of canned corn, its nearest competitor. In 1925, a pack of over 24,000,000 cases was recorded, of which about 67 per cent was baked beans. Canned limas furnish but a small proportion of this total.

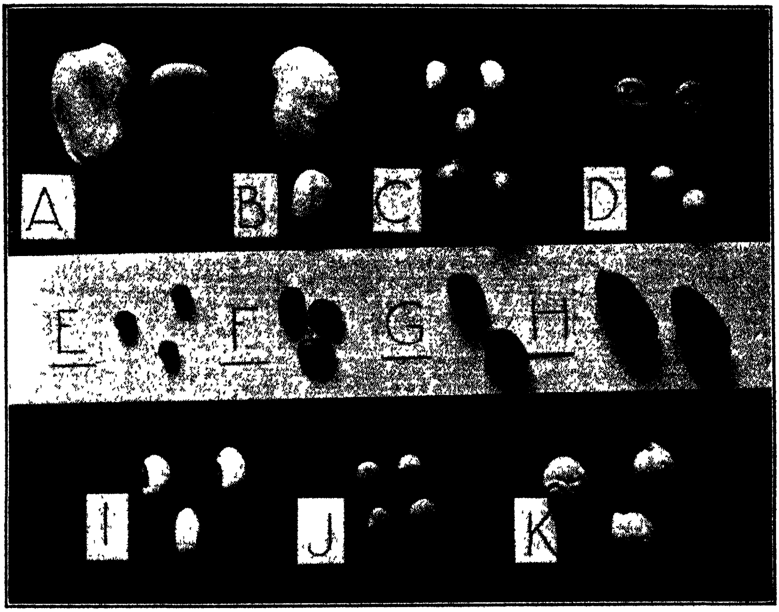

FIG. 283. — Seeds of Various Leguminous Plants. *A*, two varieties of Broad Bean (*Vicia Faba*); *B*, two varieties of Lima Bean (*Phaseolus lunatus*); *C*, two varieties of Common Bean (*Phaseolus vulgaris*); *D*, Pea (*Pisum sativum*), a wrinkled garden pea above and Canada field pea below; *E*, Common Vetch (*Vicia sativa*); *F*, Soy-Bean (*Glycine Max*); *G*, Peanut, Spanish; *H*, Peanut, Virginia (both *Arachis hypogæa*); *I*, Cowpea (*Vigna sinensis*); *J*, Lentil (*Lens esculenta*); *K*, Chick Pea (*Cicer arietinum*). The two last are popular in southern Europe and are sometimes grown in America.

Michigan leads in bean production, in some years having produced nearly one half the national total. Bean-raising is also highly developed in California and in recent years has become one of the most important agricultural interests of Idaho. The position of the United States among the principal bean-raising nations is shown in Table XI.

The Lima Bean.—The botany of the various forms of limas, sievas, and butter beans which are listed under this heading is somewhat obscure. Many botanists list all as varieties and forms of *Phaseolus lunatus;* others reserve this name for the annual smaller-seeded forms called sievas and place the large flat-seeded "true limas" under *P. limensis.*

Limas of all sorts are vigorously growing vines of twining habit, with occasional dwarf forms which have been carefully selected and bred for their greater adaptability to house-garden culture and for their (frequently) shorter season demands. The

TABLE XI

DRY EDIBLE BEANS,[1] PRODUCTION IN SPECIFIED COUNTRIES, IN THOUSANDS OF ONE-HUNDRED POUND BAGS, FOR YEARS SHOWN

COUNTRY	AVERAGE, 1921–22 TO 1925–26	1929–30	1930–31	1931–32	1932–33
Canada	736	895	863	782	636
United States	8,926	12,240	13,900	12,662	10,095
Mexico	2,600	2,094	1,774	2,870	2,583
England and Wales	3,787	2,462	3,118	2,690	2,647
France	2,410	2,249	3,119	3,284	2,287
Italy	2,345	3,468	3,490	2,692	3,950
Spain	3,398	3,438	3,631	3,427	....
Yugoslavia	[3] 1,748	2,068	3,352	2,205	[2] 2,205
Rumania	4,681	5,711	4,476	7,284	7,286
Japan [4]	1,513	2,156	2,919	1,485	1,179
Brazil	[5] 12,519	14,536	14,868	....	....
Chile	969	1,691	1,408	1,454	....
Total countries reporting, all periods [5]	31,513	36,446	40,191	40,046	36,520
Total, all countries [5]	....	56,947	61,054	....	....

From United States Department of Agriculture *Yearbook*, 1933. Bureau of Agricultural Economics. Official sources and International Institute of Agriculture except as otherwise stated. Figures are for the harvesting seasons 1921 to 1932 in the Northern Hemisphere and 1921–22 to 1932–33 in the Southern Hemisphere.

[1] Excluding soy, mung, adzuki, broad, and horse beans and similar classes not commonly used as edible beans in the United States.

[2] Unofficial estimate.

[3] 4-year average.

[4] Production in Hokkaido Province, where most of the dry edible bean varieties are grown. 3-year average.

[5] Includes several countries not listed.

limas are all probably from Tropical America; as compared with the common bean, they are even less hardy, requiring for proper development the long seasons and short hot days of warm climates. The sievas are white or variously colored; the true limas in cultivation are almost invariably white, large-seeded, and flat (Fig. 283*B*). Pods are tough and inedible. The seeds are used either green, as BUTTER BEANS or dry; some are canned. In some parts of the country SUCCOTASH, a boiled green corn and bean mixture derived from the Indians, is popular; canned succotash is generally from lima beans.

California leads in production of domestic lima beans.

Limas are extensively grown both in South America and in the Orient. In the tropics are found small-seeded lima varieties, white or variously colored, whose seeds closely resemble common pea or navy beans in shape and sometimes in color. These often contain a dangerously high percentage of a glucoside yielding the very poisonous hydrocyanic acid. They can be so prepared as to render them harmless, but as the means—and the necessity—of so doing are little known in the United States, they are refused entry to our ports. American-grown limas usually contain traces of this glucoside, but it would hardly be possible to eat enough of them to cause poisoning.

THE PEA

The Pea (*Pisum sativum*) (Fig. 277) is a cultivated plant of great antiquity. It seems to have been known to the Bronze Age Men of Switzerland and has more doubtfully been reported from Stone Age residues. It has long been cultivated in Europe; its nativity is uncertain. There are two fairly well-marked groups, the Field Pea and the Garden Pea (Fig. 283*D*), and many horticultural varieties of both, particularly of the latter.

The pea plant is a smooth, waxy, trailing and climbing vine, with pinnate leaves whose terminal leaflets are tendrils. There are many dwarf peas, favored for their earliness and for their characteristic of growing without support. The flowers are white or purplish; those of the garden pea are generally white. Blooms are characteristically self-fertilized. The seed of the field pea is angular or globular and the pod small. Field peas are mostly grown for forage; they are cold-climate plants and very hardy. Garden peas are less hardy, but still unusually frost-resistant for cultivated annuals. Pods of garden peas are tough and inedible as a rule; there is a small group of edible-podded sugar peas which are not very commonly grown. Seeds are globular when green; those of some, the wrinkled peas, shrink unevenly and become indented on drying. While the large cotyledons of the

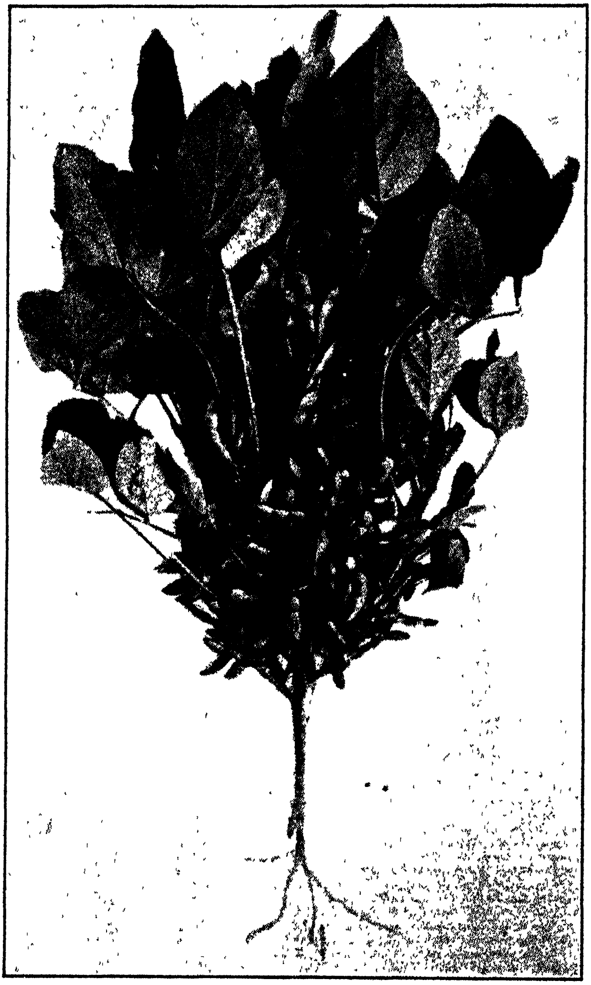

FIG. 284. — The Soy-Bean (*Glycine Max*). (Courtesy Bureau of Plant Industry.)

beans and many other legumes are carried above the soil on germination, those of the pea remain underground, serving merely as food store-houses.

Garden peas are extensively grown in house-plots and also on a larger scale. While beans are generally eaten after they have dried, peas are almost invariably cooked and canned when green. Field peas are edible, but this crop is commonly employed for soil improvement and animal feeding. In North America the field pea is commonly grown in Canada and is occasional in the Rocky Mountain region. In the South and in California it is planted in the winter.

Growth of the garden pea for fresh use and for canning is widespread, but the chief canning regions are localized in Wisconsin, New York, Delaware, Maryland, and Utah. In quantity of product the annual output ranks below beans, tomatoes, and sweet corn.

The pea has an important place in biological history. It occurs in a number of races, which, being close-fertilized, "come true" from seed when the propagating stock has been carefully selected. Thus it was used by the Austrian monk, Gregor Mendel, in researches in genetics which, published in 1866, mark the first great contribution to the scientific study of inheritance.

THE SOY-BEAN

The Soy, Soya, or Soja Bean (*Glycine* or *Soja Max*) (Figs. 283*F* and 284) is the great legume of the Orient. It is an upright, bushy, hairy annual, with trifoliate leaves and small whitish or purplish flowers produced in greatest abundance. The pods are narrow, flattened, and few-seeded. The plant has the reputation of being the most productive legume of temperate climates.

The soy-bean is a comparatively recent introduction to American agriculture. Most of its varieties do best in the warmer States, but some are adapted to the North. It does fairly well on poor soils. In this country it is grown more for soil improvement and for forage than for the seeds. These run extremely high in protein and also in oil. The soy-bean is an important oil crop, and press-cake from oil manufacture is a valuable stock food. Despite its nutritive values, which are compared with other common legumes in Table XII, the soy-bean is not popular in American diet. Because of its low carbohydrate content, it has been advocated for the use of diabetics.

In the Orient, the protein and oil of the soy-bean supplements the starch of that other staple, rice. Manchuria is the great soy-bean source of the world, and the importance of that troubled land in this respect is at least partly responsible for Sino-Japanese difficulties of recent years. The magnitude of soy-

TABLE XII

PERCENTAGE OF NUTRIENTS IN VARIOUS LEGUMINOUS SEEDS *

	Water	*Protein*	*Fat*	*Carbohydrate*
Beans, dried	12 6	22.5	1.8	59 6
Beans, lima, dried	10.4	18.1	1.5	65.9
Beans, lima, fresh	68.5	7.1	.7	22.0
Cowpeas, dried	13.0	21.4	1.4	60.8
Peanuts	9.2	25.8	38.6	24 6
Peas, dried	9.5	24.6	1.0	62.9
Peas, green	74.6	7 0	.5	16.9
Soy-bean, yellow	8.8	39.2	17.4	25.4
Soy-bean, small black	7 8	49.8	12.1	18 9
Broad bean	13.0	18 2	.8	58 6

* From Atwater and Bryant, Bull. 28, U. S. Dept. of Agriculture, except for data on the soy-beans and the broad bean, which are from Hsien Wu in *Chinese Journal of Physiology*, Report Series, 1928, No. 1, pp. 153–186.

TABLE XIII

SOY-BEANS: PRODUCTION BY THOUSANDS OF BUSHELS IN SPECIFIED COUNTRIES

CROP YEAR	UNITED STATES	MAN-CHURIA [1]	CHOSEN	JAPAN	DUTCH EAST INDIES
1922–23	[2] 4,329	109,067	23,117	18,624	3,858
1923–24	[2] 6,541	88,867	23,760	17,578	3,574
1924–25	[2] 5,680	92,667	18,723	16,596	3,536
1925–26	[2] 5,102	116,667	23,609	18,473	3,933
1926–27	[2] 6,517	135,000	22,276	12,512	3,672
1927–28	[2] 7,459	163,319	24,300	16,704	3,971
1928–29	8,688	177,804	19,510	15,239	4,303
1929–30	8,670	178,389	20,434	13,592	3,917
1930–31	12,217	193,564	22,989	15,531	4,693
1931–32	15,271	192,058	21,155	....	4,720
1932–33	13,245	[3] 163,118	[3] 22,293	....	....

Bureau of Agricultural Economics. Compiled from official sources. From United States Department of Agriculture *Yearbook*, 1933.

[1] Manchuria produces about 97 per cent of the soy-bean production of China. Production figures for China are not available.

[2] Subject to revision.

[3] Preliminary.

bean production in the United States and in certain Oriental countries is shown in Table XIII.

Few agricultural products have so captivated the interest of the industrial chemist as the soy-bean. Table XIV indicates the principal present and potential food and industrial uses of the

TABLE XIV

USES OF THE SOY-BEAN *

- Soybean
  - Plants
    - Green manure
    - Forage
      - Hay
      - Silage
      - Soiling
    - Pasture
  - Beans
    - Meal
      - Celluloid substitute
      - Stock feed
      - Fertilizer
      - Human food
        - Breakfast foods
        - Diabetic foods
        - Flour
          - Breads
          - Cakes
          - Pastry
        - Infant foods
        - Macaroni
        - Crackers
        - Soy milk
        - Bean curd
        - Soy sauce
        - Bean powder
      - Glue
      - Vegetable casein
      - Water paints
    - Oil
      - Glycerin
      - Enamels
      - Food products
        - Butter substitutes
        - Lard substitutes
        - Edible oils
        - Salad oils
      - Varnish
      - Waterproof goods
      - Linoleum
      - Paints
      - Soap stock
        - Hard soaps
        - Soft soaps
      - Celluloid
      - Rubber substitutes
      - Printing inks
      - Lighting
      - Lubricating
      - Core binder
      - Candles
      - Lecithin
    - Green beans
      - Green vegetable
      - Canned
      - Salads
    - Dried beans
      - Stock feed
        - Sheep
        - Hogs
        - Cattle
        - Poultry
      - Soy sauce
      - Boiled beans
      - Baked beans
      - Soups
      - Coffee substitute
      - Vegetable milk
        - Bean curd
          - Fresh
          - Dried
          - Smoked
          - Fermented
        - Condensed soy milk
        - Fresh soy milk
        - Confections
        - Soy casein
          - Paper size
          - Paints
          - Textile dressing
          - Waterproofing for textiles
        - Soy-milk powder
      - Breakfast foods

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* From U. S. Dept. of Agr. Farmers' Bulletin 1617.

soy-bean. Space is insufficient to comment upon them; many are at present of little moment, and the development of others is hampered by the usually relatively high price of soy-beans and soy-bean oil.

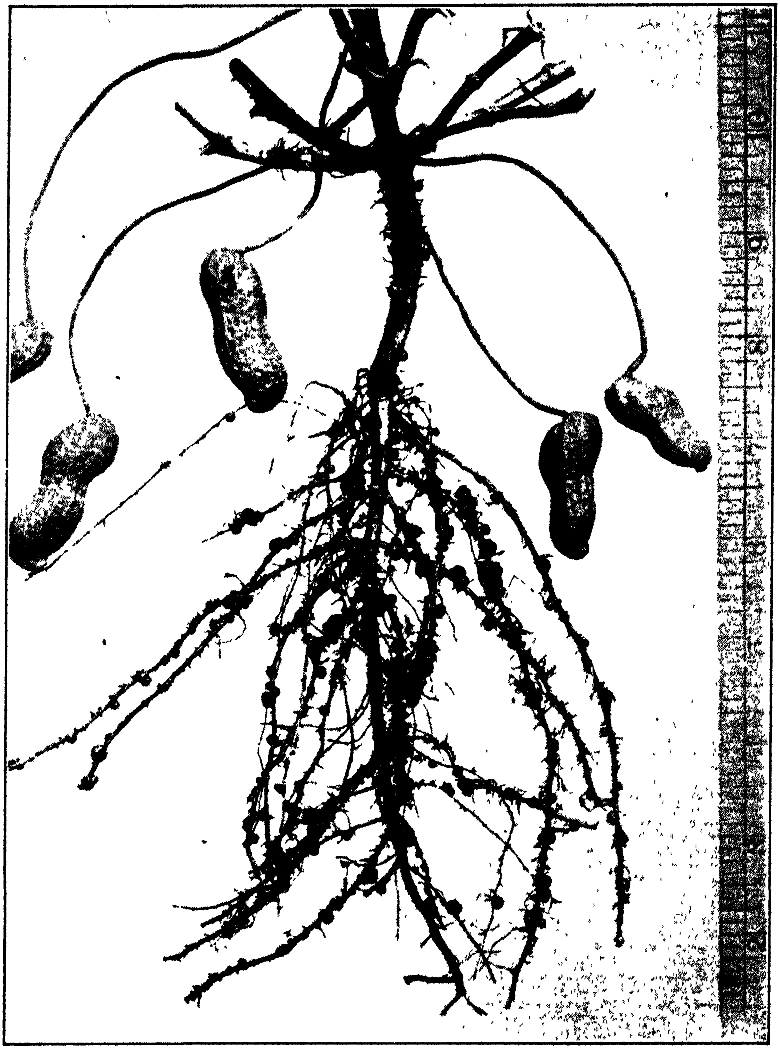

FIG. 285. — Roots of a Peanut Plant, Showing Attachment of Peanuts and Nodules Formed by the Bacteria which Collect Nitrogen. (Courtesy of Bureau of Plant Industry.)

THE PEANUT

This most interesting legume (Figs. 283*G*, *H*, 285 and 286) is probably native to Brazil; like the beans and several other tropical American crops, it was early introduced to Old World agriculture and is now widely distributed in warm and hot climates.

The peanut is a bushy annual, with pinnately compound leaves. Both sterile and fertile flowers are produced. The sterile are characteristic papilionaceous structures with long slender calyx tube, yellow corolla, functional stamens, and abortive ovary. Fertile flowers have functional pistils and no floral envelopes. After fertilization, their peduncles elongate downward, thrusting the ovary underground, where develops the well-known reticulated, indehiscent, usually two-seeded legume, the peanut. Peanuts are commonly grown on sandy soil, which is readily penetrated by the down-thrusting flowers and from which the pods may easily be removed and cleaned. They are characteristically a warm-climate crop, requiring a frost-free season of four months or more for best results.

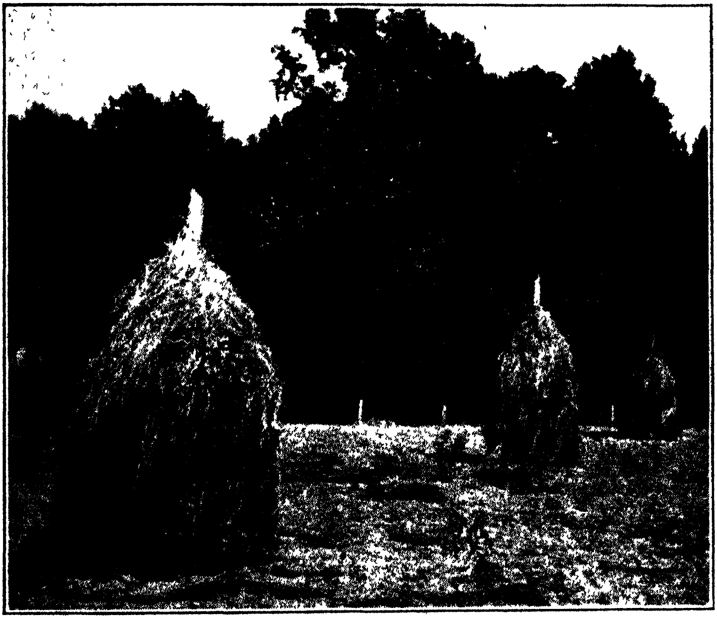

FIG. 286. — Peanuts Stacked in Field to Dry. (Photo from Texas Agricultural Experiment Station.)

Peanuts are an important crop in the sandy soil of the Atlantic seaboard and Gulf States. Georgia, Alabama, North Carolina, and Virginia lead. The annual crop of harvested peanuts of 1931 and 1932 was slightly over one billion pounds for each year, besides considerable quantities left in the ground for hog-feeding.

The uses of the peanut are so generally known as scarcely to justify listing. Great quantities are eaten roasted and salted, and millions of pounds are ground for peanut butter and crushed for peanut oil. Large amounts also are utilized in cheap candy bars, peanut brittle, and other confections. Under the low rate of duty in 1920, over 100,000,000 pounds of peanuts were imported, principally from China, whose annual crop probably equals that of the United States, although accurate statistics are lacking. India is the greatest producer of peanuts, raising over four billion pounds in a year, mostly for domestic consumption. Large quantities are also grown in Africa.

Nuts

The term NUT is a common language word which does not lend itself to scientific definition. The edible portion of most nuts is the embryo, in which are stored, usually in the cotyledons, relatively large quantities of protein and even larger amounts of oil. The coconut (Chapter XI) is the seed of a monocotyledon; here the storage is in the endosperm. The hard shell surrounding the KERNEL of nuts is generally the pericarp or a portion of it. Nearly all the nuts are products of dicotyledonous trees or large shrubs.

Most nuts are eaten raw in desserts or used in confections, cakes, etc. While they are concentrated foodstuffs, their use is limited by their usual high price and also by their reputation, not wholly deserved, for indigestibility.

The principal nuts native to the United States are the chestnut, the pecan, and various kinds of hickory nuts, walnuts, and hazel nuts. Foreign nuts cultivated here on a considerable scale are the English walnut, the almond, and exotic chestnuts, all of which are also imported in quantity. Imported nuts include brazil nuts, pistachio nuts, filberts, and a large variety of nuts less commonly seen.

Nuts of American Origin

THE CHESTNUT

Chestnuts are of several kinds, of which the American Chestnut (*Castanea dentata*), the European or Eurasian Chestnut (*C. sativa*), and the Japanese Chestnut (*C. crenata*) are the chief.

The American chestnut (Fig. 287) has already received attention in connection with the lumber and tanning industries. The tree is one of the most massive of Eastern broad-leafed species. It reaches a height of 100 feet and a trunk-diameter of three to four feet in close stands; in the open it is short boled and sometimes reaches a trunk-size of twelve feet, while the round-topped low crown may spread a hundred feet. Leaves (Fig. 118) are ovate-lanceolate and hook-serrate. Flowers are staminate and pistillate. Staminate blossoms are borne in long catkins; the pistillate ones in twos and threes in stiff-spined globular masses of modified leaves, the involucres, which mature into densely spiny burs. The individual fruit are dark brown—"chestnut" color—rounded-triangular and flattened through mu-

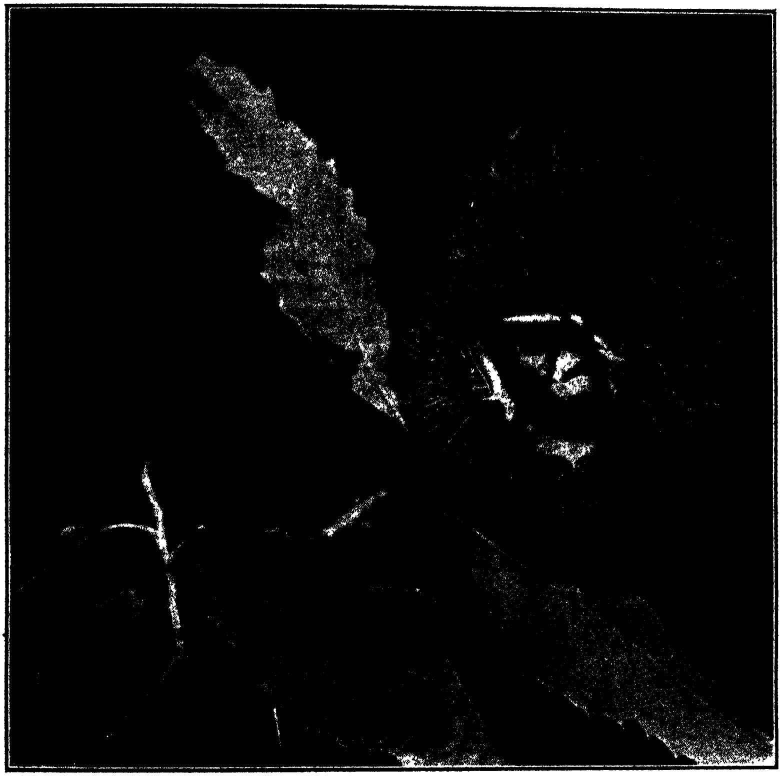

FIG. 287. — Leaf, Bur, and Nut of American Chestnut (*Castanea dentata*). (Photo from United States Forest Service.)

tual pressure, something under an inch in length. The pericarp is leathery; the seed, of two massive cotyledons, sweet and palatable. In composition, the chestnut differs from most nuts in being high in carbohydrate and low in fat and protein.

Chestnuts were an important food of the Indians of eastern North America. Until the species was attacked by the blight, they were a minor item of forest income. They have now almost disappeared from the American market. The Oriental chestnut is relatively immune to the blight; it is cultivated to a limited extent in this country. The United States Department of Agriculture has explored the hill country of China, Japan, Chosen, and Taiwan (Formosa) in search of promising varieties for introduction and for cross-breeding with the American chestnut.

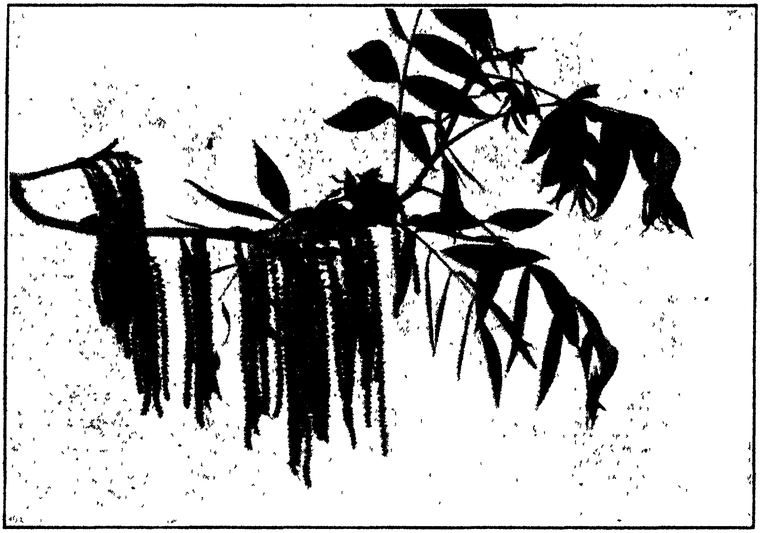

Fig. 288. — Staminate Catkins of Pecan (*Carya Pecan*).

The European chestnut, or marron, has a much larger fruit than the American species, but the quality is inferior. It is extensively grown in Italy, Spain, France, and the Orient. Italy leads in production; the average annual harvest for 1922–1926 was 1,119,000,000 pounds. American imports of foreign chestnuts, mostly Italian, range from 20,000,000 pounds to 25,000,000 pounds annually.

Chestnuts, like most starchy foods, are generally cooked before being eaten. They may be roasted or boiled; chestnut flour is made in Europe.

THE PECAN

The Pecan (*Carya* or *Hicoria Pecan*) is a large handsome tree, of hard wood, found in river bottoms and rich soil from Indiana and Iowa southward to Mexico. The leaves are large and pinnate-compound. The flowers are staminate, borne in catkins (Fig. 288), and pistillate, in small clusters. The outer portion of the pericarp is leathery and dehiscent; the inner, enclosing the seed, thick, pointed or with blunt ends, and variable in size and thickness.

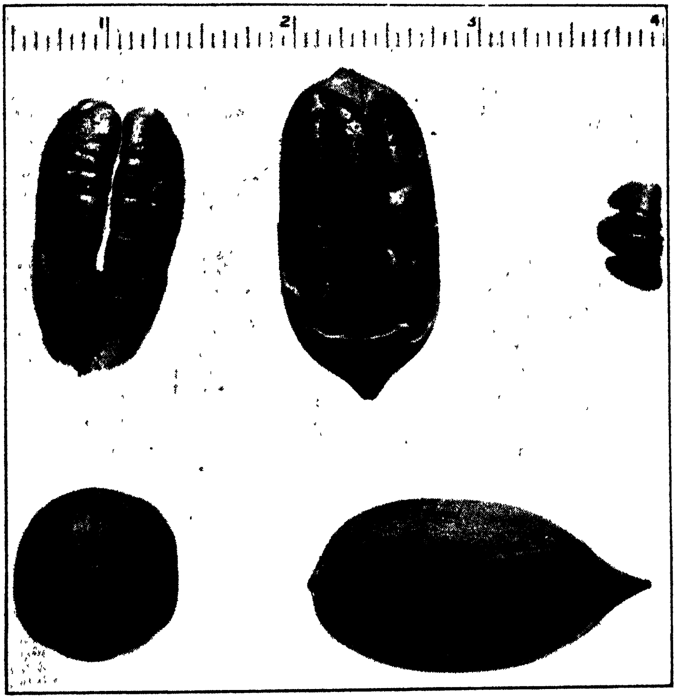

FIG. 289 — Nuts and Kernels of the Schley Pecan. (Courtesy Florida Experiment Station.)

The pecan is abundant in the southern part of its range, and large crops are gathered from wild trees in Texas, Oklahoma, and the Gulf States. In the last half-century extensive plantations have been set, of selected "paper shell" pecans (Fig. 289) of several varieties, chosen for thinness of shell and sweetness of kernel. The pecan is now by far the most important native nut, though less profitable in production than its price might lead the novice to believe. The maximum harvest, that of 1931, reached nearly 78,000,000 pounds, of which over half came from Texas and Oklahoma.

OTHER NATIVE NUTS

The Hickories.—The hickories are of the same genus as the pecan. Several species are quite widely distributed in the eastern hardwood forest. The nuts of most of them are small and hard-shelled and often bitter. Those of the Shagbark (*Carya* or *Hicoria ovata*) (Fig. 290*C*) were prized by the Indians and early settlers and appear in small quantities in the modern market. One or two thin-shelled varieties have been locally planted. The chief importance of the hickories, however, is as timber and fuel species.

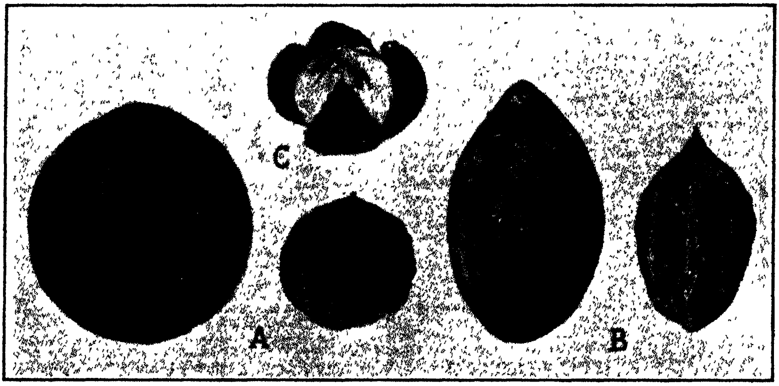

FIG. 290. — Native Nuts. *A*, fruit of Black Walnut (*Juglans nigra*), with the nut at the right; *B*, Butternut (*J. cinerea*); *C*, Shagback Hickory (*Carya ovata*), showing dehiscence of husk. (From J. H. White, *Forest Trees of Ontario*, Dept. of Lands and Forests, Ontario, 1925.)

The Walnuts.—About six species of *Juglans* (Walnut) occur within the United States. Of these the best known is the Black Walnut (*J. nigra*), which has been referred to in connection with the furniture industry. The nuts (Fig. 290*A*) are flattened-globular, about an inch in length, surrounded by a soft indehiscent husk which dries and blackens as the fruit cures. The nut is hard-shelled, rich in oil, rather strong-flavored, and not extensively used. More highly valued for nut-production is the Butternut (*J. cinerea*) whose rough-shelled, ovate and pointed nut (Fig. 290*B*) is beloved by the farm population wherever it grows. It occasionally appears in the Eastern market. The rather small kernel is high in protein, with a yield of nearly 28 per cent. The tree does not take kindly to cultivation; the small yield and the hard shell of its fruit also militate against extensive production.

In California occur two closely allied species of walnuts, much resembling the black walnut, but smaller and with even less valuable nuts. They are used chiefly as grafting-stock for the English walnut, which in California is rarely grown on its own root system.

Acorns and other nuts.—The numerous American oaks bear acorns of varying quality, usually bitter and rich in tannin. Many of these were used by the aboriginal population, but they have little economic significance now save where they are plentiful enough for hog-feed—a use for which they are more highly valued in the forests of Europe. The Beech (*Fagus grandifolia*) bears small sweet triangular nuts which are gathered to some extent in Canada. Several species of American hazel, allied to the filbert, occur, but their nuts are small and likely to be infested with insect larvæ.

Pine Nuts are the hard-shelled seed of several species of pines of the Californian and southwestern mountains. They are important in Indian diet and occasionally appear in the market. Certain European pines of Italy and the Levantine region also yield edible seeds, which are imported into America as "pignolia" and used as salted nuts, confectionery, etc. They are of considerable dietary importance in the countries where they occur.

Exotic and Foreign Nuts

THE ENGLISH WALNUT

The so-called English Walnut (*Juglans regia,* Fig. 291) is probably Persian in origin. It is an important crop in France, Italy, Rumania, Spain, and Turkey and in northern China and Manchuria. The nut came into early American commerce through English ports; hence the name which in colonial days served to distinguish it from the black walnut.

The English walnut is a vigorous round-headed tree reaching a height of seventy feet or more, with large pinnately compound leaves. The green husk of the fruit cracks on ripening, allowing the comparatively smooth-shelled ovoid or ellipsoid nut to fall out.

The English walnut is not hardy enough for successful cultivation in the Northern States and is only occasionally seen in the South. Nearly the entire American production comes from central and southern California, where the industry is highly organized, both agriculturally and commercially. There are smaller plantings in Arizona and Oregon.

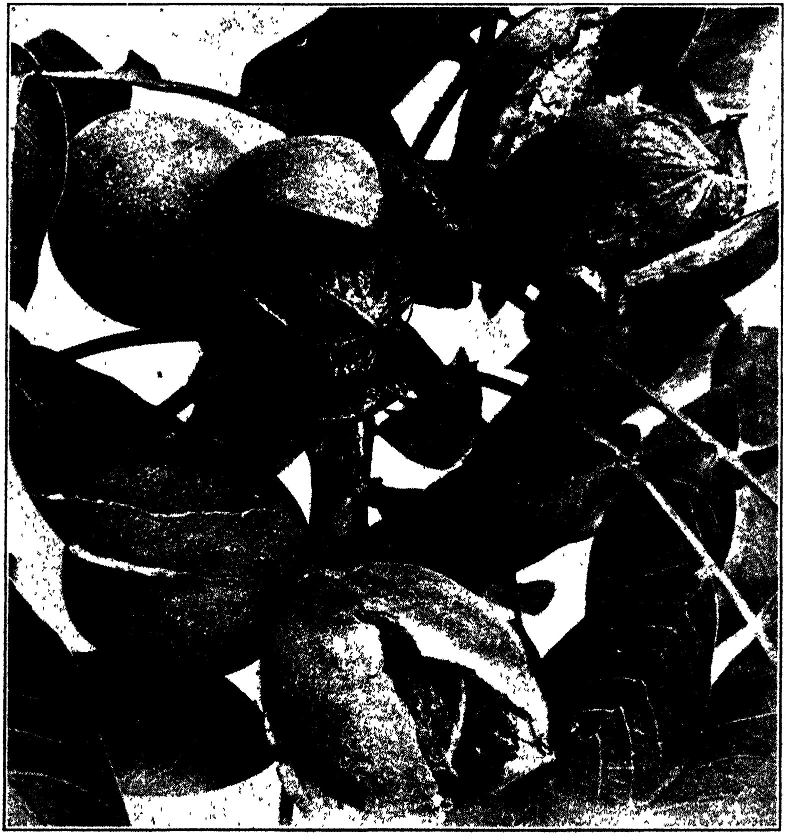

FIG. 291. — English Walnut (*Juglans regia*). Note the dehiscence of the hull surrounding the nut. (Courtesy of California Agricultural Experiment Station.)

The English walnut, like other members of the genus, does not thrive on poor soil. Most plantations are on high-priced irrigated land. Selected varieties are budded or grafted, usually on the stock of the Northern California Black Walnut (*Juglans Hindsii* or *J. californica* var. *Hindsii*) which is more resistant to a common root-rot than is the English walnut itself. Walnuts come into bearing at between five and nine years and produce profitable quantities after about ten years. The average annual yield of nuts is stated to be about 800 pounds per acre. Most of the Californian plantations are of comparatively young trees; judging from Old World experience, these should continue to bear for a hundred years or more. The nuts fall from the tree on ripening, but they may be hastened by shaking. Preparation for market includes washing, drying, bleaching, and very careful sorting into standardized grades. Marketing is mostly done by cooperative associations.

The Californian crop is subject to great fluctuation, yields of 1926, 1927, and 1928 being respectively 30,000,000 pounds, 102,000,000 pounds, and 50,000,000 pounds. Except in unusual years like 1927, the Californian output supplies about 40 per cent of the walnuts used in the United States. France, Italy and China afford most of the rest. The better grades of Californian walnuts are usually sold in the shell. Demand for shelled walnuts is mostly supplied from abroad. About three pounds of walnuts in the shell supply one pound of shelled kernels. A comparison of the food values of walnuts with that of other products of their class is given in Table XV.

TABLE XV

PERCENTAGE OF NUTRIENTS IN EDIBLE PORTION OF VARIOUS NUTS.*

	Water	*Protein*	*Fat*	*Carbohydrate*
Almonds	4.8	21.0	54.9	17.3
Brazil nuts	5.3	17 0	66.8	7.0
Butternuts	4.4	27 9	61 2	3.5
Chestnuts, dried	5 9	10 7	7 0	74 2
Coconuts	14 1	5 7	50.6	27.9
Filberts	3.7	15.6	65.3	13.0
Peanuts	9.2	25.8	38.6	24.4
Pecans, polished	3.0	11 0	71.2	13.3
Walnuts, California, black	2.5	27.6	56 3	11 7
Walnuts, English, from Calif.	2 5	18 4	64 4	13 0

* From Atwater and Bryant, Bull. 28, U. S. Dept. of Agriculture.

THE ALMOND

Almonds are from *Prunus Amygdalus,* also known as *P. communis* and *Amygdalus communis,* a relative of the peach. The tree somewhat resembles the peach in appearance, but is larger and longer of life. Its foliage has a somewhat grayish aspect. The pale pink flowers (Fig. 292) are produced even earlier than those of the peach and thus are subject to considerable frost hazard. The structure of the fruit (Fig. 293) resembles that of the peach, but in the almond the fleshy portion (mesocarp) is tough, leathery, and more or less dehiscent. The almonds of commerce correspond to the peach stone and its contents; the edible portion is an ovoid or ellipsoid seed, rich in protein and oil.

There are two principal types of almonds, the bitter and the sweet. Bitter almonds contain a poisonous glucoside, which liberates hydrocyanic acid. Small quantities of bitter almonds are grown in the Mediterranean region, being used in the manufacture of flavoring preparations and of hydrocyanic acid. The sweet almond is the chief almond of commerce, being valued for oil-pressing, soap manufacture, and for dessert and confectionery use. There are two types of sweet almond, hard-shelled and soft-shelled, and many varieties of each type.

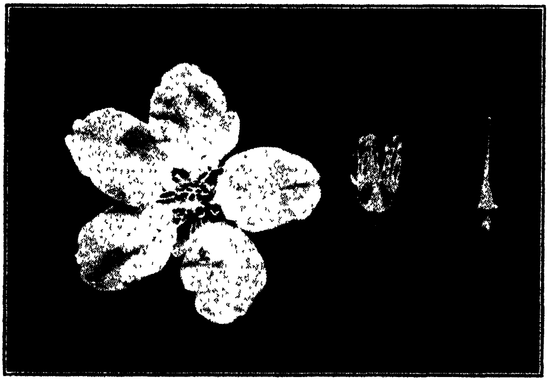

FIG. 292. — Flower of the Almond (*Prunus Amygdalus*). At the right are shown a flower with calyx-lobes and corolla removed and a pistil from a slightly older flower. (Courtesy of College of Agriculture, University of California.)

In the United States, almonds are little grown outside California. In that State the annual production usually ranges between 24,000,000 pounds and 30,000,000 pounds. Imports of almonds, mostly from Spain, France, and Italy, range around 72,000,000 pounds annually in terms of shelled nuts. A very large proportion of imports are shelled almonds. Three pounds of almonds afford about one pound of kernels.

European almond culture is an incidental rather than large-plantation enterprise, trees being planted along roadsides and fence-rows and on hillsides, but the aggregate production is considerable. The Italian crop ranges between 250,000,000 and 350,000,000 pounds annually; that of Spain in the neighborhood of 200,000,000 pounds.

THE BRAZIL NUT

Brazil nuts, known also as cream nuts and less formally as "nigger-toes," are the large, hard-shelled seeds of *Bertholletia* *excelsa,* a huge forest tree of northern Brazil. From eighteen to twenty-four of these nuts are borne in a hard globular capsule six inches or more in diameter. The dropping of such things from a height of 100 feet or more adds a trifle to the hazards of the tropical forest. They are indehiscent and have to be cracked to secure the nuts. The related monkey-pot tree bears similar nuts in a capsule which resembles an iron pot opening by a lid; these nuts occur in less accessible parts of South America and are not often seen in commerce.

FIG. 293. — The Almond (*Prunus Amygdalus*). (Courtesy of California Agricultural Experiment Station.)

In structure, the Brazil nut is a botanical curiosity. The tree is classed as a dicotyledon, but the cotyledons fail to develop. The white oily kernel is the rudiment of stem and root. Besides its well-known dessert and pastry uses, it furnishes a fine quality of oil used in salads, in paints, and for lubricating watches.

The United States and Brazil are the principal markets for Brazil nuts. Our annual imports have varied from 21,000,000 to 45,000,000 pounds of these delicacies, besides from 1,000,000 to 3,000,000 pounds of shelled kernels.

THE FILBERT

The filbert is the small round nut of *Corylus Avellana,* an Old World shrub closely related to our native hazels. It is produced chiefly in Italy; culture on a small but promising scale is reported from Oregon. We utilize from 10,000,000 to 15,000,000 pounds of unshelled filberts, as well as from 3,000,000 to 6,000,000 pounds of imported kernels, each year. They are used by bakers, biscuit manufacturers, confectioners, etc., and are a common—and often disappointing—ingredient of "mixed nuts."

OTHER NUTS

The tropical world affords many nuts and so-called nuts rarely seen in the American market. Among those of some degree of familiarity are pistachio nuts, the product of *Pistacia vera* of the Mediterranean region. The nut is about an inch in length, with a greenish and characteristically flavored kernel. It is utilized in confections and ice creams and as a roasted and salted dessert nut. A related product is the cashew nut, the seed of *Anacardium occidentale* of Brazil. The fruit has a huge swollen peduncle, the cashew apple, much larger than the fruit proper, and brilliant yellow or scarlet, and juicy. Below this appears the kidney-shaped true fruit, whose kernel is the cashew nut which is roasted and salted for American desserts.

The "litchi nut," beloved of the Chinese, is a nut only by great extension of the term. The fruit has a remote resemblance to a strawberry of rounded contour; the outer portion is a hard and brittle shell surrounding a fleshy aril, or seed-enwrapment, which is the edible part. Fresh litchis are considered a great delicacy; the "nut" is the dried product as imported into this country.

CHAPTER XIII

FOOD PRODUCTS: CERTAIN FRUITS

The Nature of Fruits

The term FRUIT, in the botanical sense, may be defined as referring to the ripened ovary and its attachments. In commercial usage the word is commonly restricted to edible products, and generally to those which may be eaten without cooking. It is here contrasted with another even more vaguely defined common language conception, the vegetable, which generally includes such crop products as squashes, melons, and even tomatoes, all of which are, botanically, perfectly good fruits.

As all normal flowering plants produce fruit of some sort, it may readily be understood that the edible fruits of the world are drawn from many botanical families. In North America the preëminent groups are the Rosaceæ, whose apples, pears, peaches, and strawberries span the entire arable nation, the citrus group of the Rutaceæ, restricted to near-tropics; and the grapes of the Vitaceæ, a widespread crop whose commercial production is quite localized. Among widely diverse families are the figs, the currants and gooseberries, the olives, the bananas, the pineapples, the persimmons, the avocados, and many others.

The Food Value of Fruit

Generally speaking, the edible portion of fruit is the pericarp or some portion of it; in some important groups, particularly in the Rosaceæ, a much modified portion of the stem, the receptacle or hypanthium, is eaten. These portions are usually highly juicy and flavored pleasingly with citric, malic, or other organic acids, plus traces of characteristic aromatic substances, and with appreciable sugar content. Of the three principal foodstuff categories, fruits rank highest in carbohydrates; with a few exceptions, their protein and fat values are negligible. They are chiefly valued for their appeal to the appetite and for their roughage (cellulose) content. Their seeds are commonly covered by hard and indigestible integuments—a factor which is of considerable importance in the dissemination of species bearing berries and small stone-fruits. The kernels of many of the larger seeds, particularly those of the Rosaceæ, are bitter or poisonous; thus their considerable protein and oil content is frequently unavailable for human use.

The Production of Fruit

The commercial fruits are for the most part highly developed above their original wild state by selection and breeding. They are almost invariably propagated by asexual means. As compared with the cereals, they require high quality in soil, careful culture, and considerable hand labor—particularly in picking and packing seasons. Collectively, they are of wide climatic adaptibility, but successful production of any fruit on a large scale is apt to be quite localized. As a class, they do not thrive in the great cereal regions. High winds and cold winters militate against them. As compared with many other agricultural operations, fruit-farming is a small-scale interest, though in some cases a high degree of coöperation binds large areas into a considerable degree of uniformity of management.

The Marketing of Fruit

Ripe fruit is among the most perishable of products. Under natural conditions, juicy portions decay or are eaten by animals, liberating seed. Most fruit kinds, also, ripen within a comparatively short period. Prompt picking and speedy marketing are essential. On the farm, overload of work often comes at a critical period, and the unevenness of labor demand is likely to bring dependence on migratory and often unsatisfactory labor.

Fruit seasons may be lengthened by varietal differences in ripening, and, for the country as a whole, by culture over such range of latitude as the nature of the product permits. Some fruits, such as apples and oranges, may be held long periods in cold storage; others, such as peaches and strawberries, cannot. The comparatively recent development of the refrigerator car now enables even very perishable fruits to be shipped considerable distances. Freezing fruit for storage has usually been avoided as impairing flavor. Development of new methods of extreme-cold refrigeration seem likely to develop into commercial importance. Canning, drying, and preserving of particular fruits—such as the peaches and prunes of California—are important industries, extending the ultimate marketing of many most perishable fruits throughout the year.

Among the most potent factors in the profitable marketing of some fruits have been coöperative associations. These are best developed in California, where orange-growers blazed the trail. The more successful of these associations organize a virtual monopoly of their product; they establish standards and maintain rigid grading systems; they employ highly efficient marketing specialists who keep in close touch with the markets of the world. They own or lease warehouses, terminals, trucks, refrigerator cars. If they do not actually make prices, they maintain them by regulation of output and by abandonment or destruction of surpluses which might break the market. Above other corporations, they are favored by federal and State laws. They seem to point the way, in short, to a more profitable agriculture, and it has become more and more evident that adoption of their methods offers promise for the needed relief of general farming.

Many of the crop-control regulations promulgated by the federal government in 1933–1934 were apparently patterned upon measures previously worked out by the fruit coöperatives.

Fruit Crops of the United States and Their Distribution

The accompanying map (Fig. 294) enumerates and illustrates the distribution of the major fruit crops of this country. More detailed discussion of individual distributions will be found in the following pages.

I. FRUITS OF THE ROSACEÆ

Listed in the general order of volume and value-production, these include the pomaceous fruits of the Pomoideæ (Malaceæ), the apple, pear, and quince; the drupaceous fruits of the Prunoideæ (Drupaceæ); and the rosaceous products of the Rosoideæ, strawberries, raspberries, blackberries, etc. The first two groups are among the tree fruits of the horticulturist, and the rosaceous fruits among the small fruits—although there is nothing particularly small about a well-grown strawberry.

The Apple

This well-known fruit has good claim to first rank among American and among all temperate zone fruit products. It is also one of the widest in range of culture.

The botanical classification of the apple is a matter of some difficulty. Commercial apples are probably derivatives of *Malus* or *Pyrus sylvestris,* the Wild Apple of Europe, and perhaps are somewhat hybridized with other species. Not only do the apples,

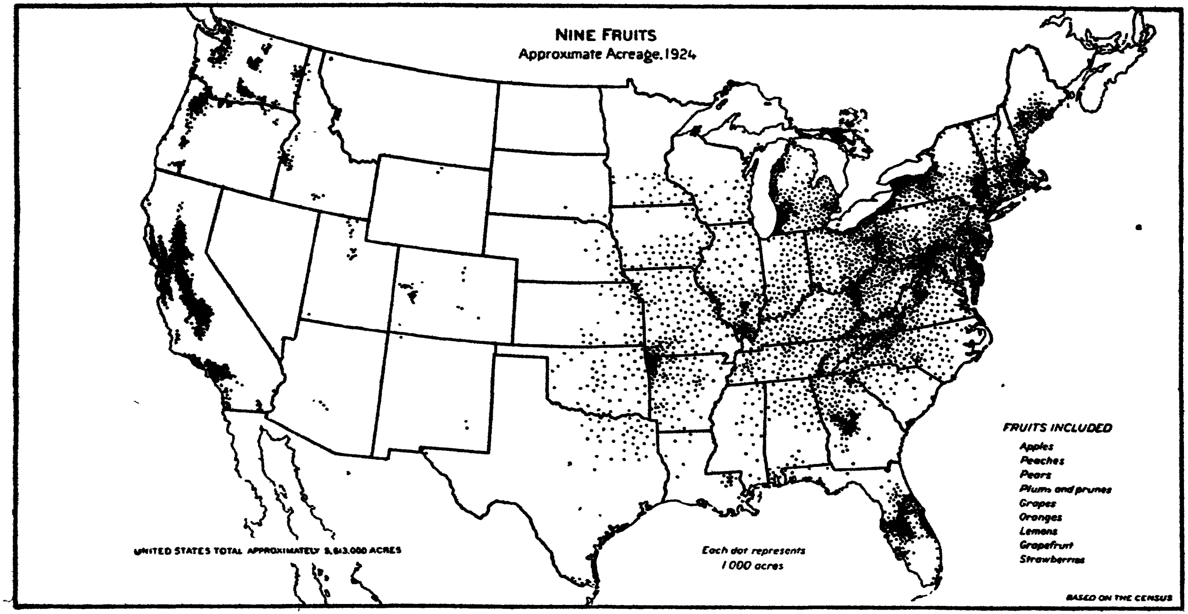

FIG. 294. — Fruit Crops of the United States. California contributes over one-sixth of the nation's acreage of fruits and nuts and over one-third of the value. The district in southern California grows mostly citrus fruits, walnuts, and apricots; that in central and northern California grapes, peaches and apricots, plums and prunes, with some citrus fruits and pears in the foothills and apples near the cool coast. The dots in Florida represent mostly citrus fruits; those in the Cotton Belt, especially Georgia, peaches; and those in extreme western New York and southwestern Michigan, grapes. Elsewhere in the United States, with few exceptions, the apple is dominant. (From United States Department of Agriculture *Yearbook*, 1928.)

like most rosaceous genera, hybridize readily, but they seem also subject to much variation and probably mutation, characteristics which have been factors in the present development of the apple and the apple industry.

Several small-fruited wild species, both European and American, are known as crab-apples. Crab-apples cultivated for their hard acid fruit are descendants of *Malus baccata*, the Siberian Crab, perhaps with a mixture of ordinary apple "blood."

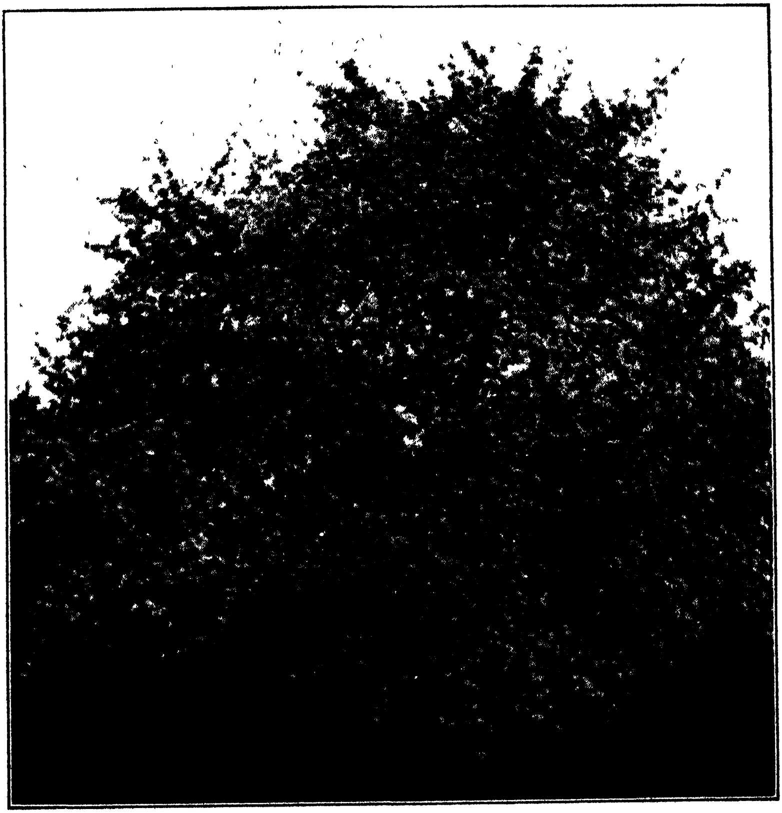

FIG. 295. — A Well-Shaped Apple Tree in Full Bloom. (Courtesy of Bureau of Plant Industry.)

THE APPLE TREE

As seen in cultivation (Fig. 295) the apple tree is low crowned and round-headed, forty feet or less in height. In some parts of its range, as in New England, it may reach over 100 years of age. Under orchard conditions, trees often become unprofitable in forty years or less. Because of the difficulties of picking fruit from high trees, the apple (and also most other orchard trees) is not, generally, allowed to reach its maximum height.

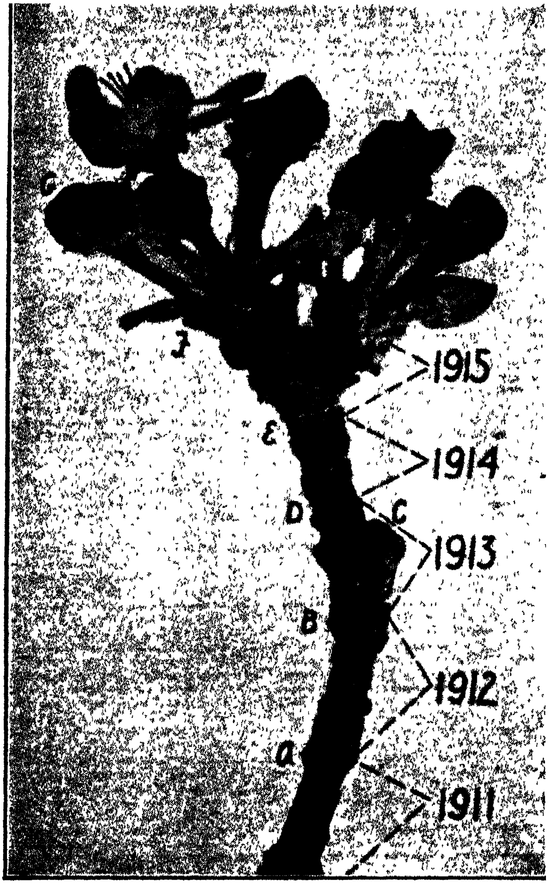

FIG. 296. — A Fruit Spur of the Apple. The increment of each year is indicated. (From Robbins, *Botany of Crop Plants*, P. Blakiston's Son & Co., Inc.)

The wood of the apple is hard and dense, with thin sapwood and reddish heartwood. It is valued for tool-handles, and, when thoroughly dried, for fuel. Little reaches the market.

The leaves are herbaceous and simple, rather dull green, often pubescent beneath. Stipules are present on those of young shoots, but may be lacking on those of older wood. Fruit is borne on short-shoots or spurs; which are terminated in winter by thick rounded buds, containing primordia of both blossoms and leaves. Usually a spur (Fig. 296) is two or more years old before it bears; thereafter its growth is but a fraction of an inch a year, in a sort of irregular zigzag marked by annulations of leaf-scars and circular, stubby wounds left by the falling apples of each year. Rather rarely, fruit buds may be produced in axils on the rapidly extending shoots of the current season.

Leaves and flowers unfold together; the pale green of foliage, with the white and faint rose of bloom, making a blossoming apple orchard a sight never to be forgotten. Flowers occur in terminal umbel-like cymes; many drop soon after opening, and fruit of others is shed at intervals throughout the growing season, so that often only one apple matures on a spur.

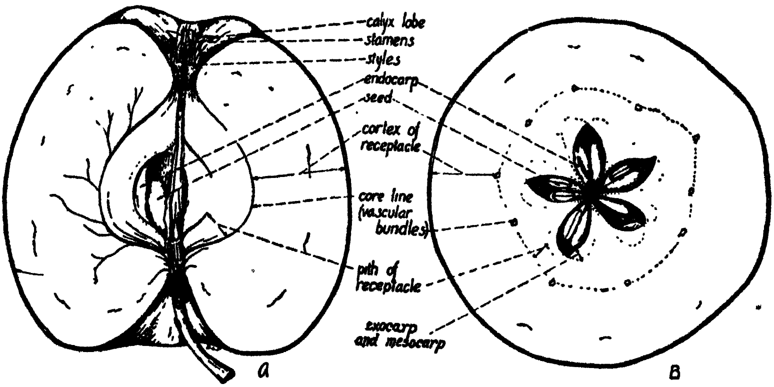

FIG. 297. — Sectional Views of the Pome of an Apple. This illustrates the theory which derives the principal bulk from the receptacle. If this theory be correct, we eat the stem and throw the fruit away. (From Robbins, *Botany of Crop Plants*, P. Blakiston's Son & Co., Inc.)

The flowers possess five sepals, five petals, and numerous stamens in three whorls above and around five carpels which are sunken in and surrounded by a complex structure which some botanists believe to be mostly calyx tube, while others consider it to be composed of modified stem tissues. After fertilization, rapid growth goes on in the tissues surrounding the carpels. The ripened structure of specialized tissue and enclosed carpels is technically known as a POME (Fig. 297); it is the characteristic product of the Pomoideæ.

The blossom of the apple, like most showy flowers, is insect-pollinated. Pollen is often poorly developed—a frequent characteristic of hybrids. Many apple varieties are self-sterile, failing to fruit unless pollinated by some other variety. In large orchards, several varieties are commonly planted in blocks or alternate rows to insure cross-pollination. Beehives are often brought in at the blooming season.

In its early stages, apple flesh is hard, greenish, rich in starch and malic acid. During ripening, starch is replaced by sugar, the acid diminishes, and the flavors and aromas (due partly to complex esters) which characterize the various species, develop. The pectins of the middle lamella partially dissolve, and in overripeness the flesh becomes mealy and insipid.

PROPAGATION OF THE APPLE

Apple trees can readily be raised from seed; in the older settlements of the East the trees commonly occur wild, particularly in old pastures where seeds have been scattered in droppings of cattle. In the early settlement of the Ohio Valley an eccentric wanderer known as Johnny Appleseed scattered bushels of seed in that region. Volunteer apples, however, are typically small, sour, or bitter—worthless for anything but cider and inferior for that; they are a menace furthermore, in harboring insects and fungus parasites which spread to cultivated orchards. From millions of chance seedlings and, in recent years, from more or less scientific breeding, have sprung perhaps two or three thousand named apple varieties. Probably not more than a hundred of these are of real commercial significance, and a much smaller list furnishes the bulk of the apple product of the United States. Commercial varieties are propagated by grafting or budding seedling stocks or root cuttings. As stock material may be of variable or unknown hardiness, root-grafting, with the union below the soil-level, is advocated for the hardy kinds best adapted to cold climates.

The principal production of fruit tree stocks of all kinds is in the Kaw Valley region near Topeka, Kansas, and in the Pacific States. In 1928, in the United States, 30,105,000 apple seedlings for propagation were produced.

While most commercial propagation is on small stocks, old trees may be cut back and top-worked; many ancient and unprofitable New England orchards have been revived in this way. Apple fanciers with a liking for variety cherish old trees on whose spreading limbs have been grafted a dozen or more apple kinds, of varied flavors and seasons.

Apple trees may be grown as dwarfs by grafting on stocks of smaller growing, nearly related species, such as the Paradise Apple (*Malus pumila*). The small absorbing capacity of the stock root-system retards the vegetative growth of the scion, adapting the dwarfed apple to growth in backyards or to close planting of many varieties in limited area. Size and quality of fruit are not adversely affected.

ENVIRONMENTAL RELATIONS AND PRODUCTION

Apples are among the most widely grown of fruits. The tree is considered a hardy one, and its cultivation ranges in some parts of the world to 65 degrees north latitude—though not usually to much advantage. Winter injury often occurs, however, and the blossoms are even more frost-sensitive than those of the peach, being saved by their later opening habit. The apple does not thrive in warm climates.

Apples are subject to numerous diseases and insects, which affect both plant and fruit, but these can usually be controlled by proper spraying. Fire-blight, the worst enemy of pear and quince, affects the apple less seriously.

Among commercial apple varieties are many differences in hardiness, disease-resistance, and in climatic and soil adaptability.

The principal apple-growing regions of North America are in northerly and mountainous regions where the winter temperature rarely sinks below −20° F. and where summers are fairly warm and humid. Fig. 298 illustrates the commercial distribution of the apple in the United States.

New England; the region below Lake Ontario in New York; the Alleghenian valleys of Maryland, Pennsylvania, and Virginia; the Ozarks; the Pacific Northwest; and the middle altitudes of the Sierras in California are our chief centers of production. All of these localities tend to concentrate upon particular varieties. The apple crop fluctuates greatly from year to year (Table XVI). A "bumper crop" of nearly 247,000,000 bushels was recorded in 1926; that of 1927, the smallest of recent years, was almost exactly half that. Washington and New York lead other States; Virginia usually ranks next. About half the American crop is locally consumed; the rest is the commercial crop.

APPLE VARIETIES

Apples vary widely in season, character, and appearance. Among widely known summer varieties are Yellow Transparent and Red Astrachan. Autumn types include Gravenstein and Oldenburg. Winter varieties are the most numerous, forming the bulk of the apple crop. McIntosh, Baldwin, and Rhode Island Greening are standards in the East, and Jonathan, Winesap, and Delicious in the West. Apples are valued for their appearance, flavor, and keeping quality. Some kinds are among the most easily kept of fruit. Between natural variation of ripening time and the development of cold storage and shipping facilities, American apples are now available every day in the year.

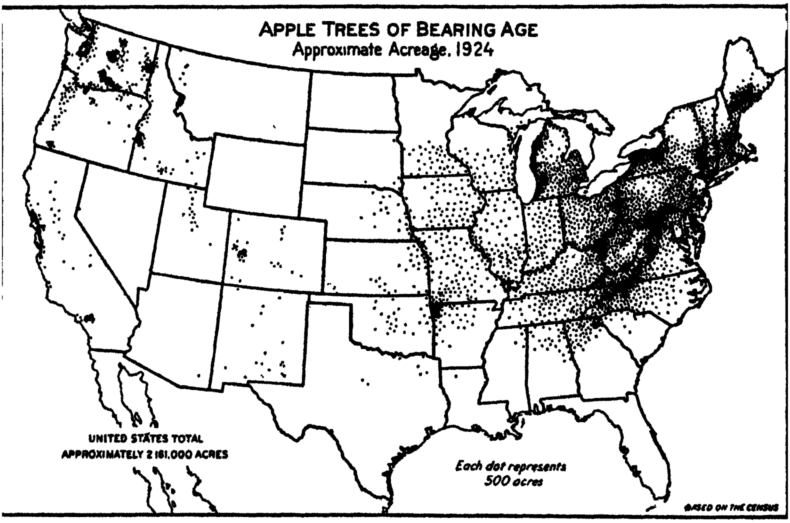
APPLE TREES OF BEARING AGE
Approximate Acreage, 1924
UNITED STATES TOTAL
APPROXIMATELY 2 161,000 ACRES
Each dot represents
500 acres
BASED ON THE CENSUS

FIG. 298. — Apple Trees of Bearing Age in United States, 1924. About 14 per cent of the acreage of apple trees of bearing age was in the West in 1924, and nearly half of this Western acreage was in the State of Washington. New York, Pennsylvania, Ohio, Michigan, and West Virginia, however, exceeded Washington in acreage. Most of the apple acreage is found in the hay and pasture region from Maine to West Virginia and Michigan, where the climate is cool, but, owing either to lake or mountain protection, the winters are more moist and less severe than in the interior. The southern limit of the apple area extends only a little beyond the northern limit of cotton, and the western, or moisture, limit, is about the same as that of timothy. In recent years, Western planting of trees has considerably slackened; most of the acreage of young trees (not shown in the above map) is in the East. (From United States Department of Agriculture *Yearbook*, 1928.)

Appearance of apples seems to influence consumer demand more than any other quality; even flavor, particularly if the fruit is to be eaten uncooked. Most commercial varieties are red or red-striped, with mild, sub-acid flavor. Sugar content of apple varieties is rather constant at about 10–12 per cent of the juice content; the malic acid, and therefore the evident sourness, varies considerably. Varieties of low acid content are quite sweet but are too insipid for modern market demands. Baked sweet apples and bread and milk, once a standard country supper, has almost faded from the American picture.

USES OF APPLES

Apples are chiefly used fresh and for domestic cooking. Dried apples, apple preserves, and apple jellies are commercial products; canned apples are of minor importance. Crab-apples—small hard fruit of high acid and pectin content—are valued for jellies; and apple juice and pectin are mixed with more highly flavored and expensive fruits in jellies and preserves. Cider, the juice of apples, is pressed from culls. After alcoholic fermentation, it may be further changed to vinegar through action of acetic acid bacteria. While vinegar is also made from malt products and from other saccharine fruit juices, cider vinegar is favored in the American market. Pomace, the refuse from the cider-press, is a commercial source of pectin.

TABLE XVI

APPLES: PRODUCTION BY THOUSANDS OF BUSHELS IN THE UNITED STATES FOR YEARS STATED

YEAR	PRODUCTION		YEAR	PRODUCTION	
	Total	*Commercial*		*Total*	*Commercial*
1919	*136,561*	....	1926	246,609	117,384
1919	142,086	78,477	1927	123,693	78,051
1920	223,677	101,715	1928	186,893	106,383
1921	99,002	64,671	1929	*126,433*	....
1922	202,702	95,835	1929	133,347	86,664
1923	202,842	107,808	1930	153,324	100,587
1924	*152,967*	....	1931	202,415	103,776
1924	174,725	84,039	1932 [1]	[2] 139,156	84,819
1925	172,389	99,738			

From United States Department of Agriculture *Yearbook*, 1933. Bureau of Agricultural Economics. Production figures are estimates of the Crop Reporting Board; italic figures are census returns. Prices to producers are based upon returns from crop reporters. Estimates of production for 1929 and 1930 revised on basis of 1930 census. Earlier years not so revised.

[1] Preliminary.

[2] Includes 220,000 bushels not harvested on account of market conditions.

WORLD TRADE IN APPLES

Apples are grown throughout northern Europe, but international trade there is not great. Canada produces 3,000,000 to 5,000,000 barrels annually, mostly in Nova Scotia and British Columbia, and is the source of nearly all the small apple imports of the United States. The United States and Canada are the great national exporters of apples, which go chiefly to northern Europe. Tasmania, and to a lesser extent New Zealand, supply apples from the Antipodes between the ripening seasons of northern hemispheres.

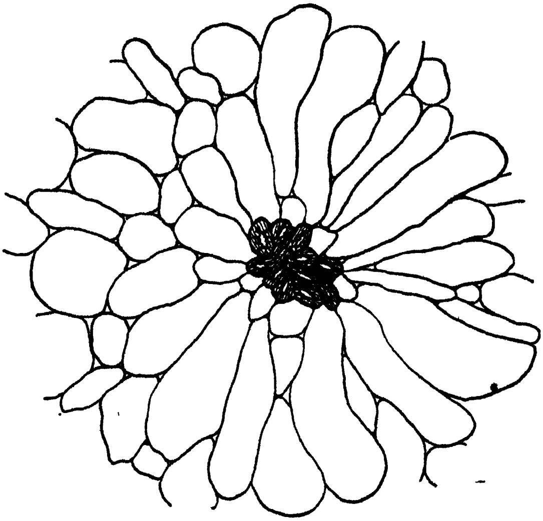

FIG. 299. — Stone-Cells of the Flesh of the Pear, Surrounded by Parenchyma. (E. Coffman.)

The Pear

Most of the widely grown pear varieties are derived from the Eurasian *Pyrus communis;* a few are from the Chinese Sand Pear, variously known as *Pyrus pyrifera, P. communis* var. *culta,* etc., and others are hybrids of the two.

The pear tree in many respects resembles the apple; it is somewhat taller and of more upright habit. Its hard dense wood is sometimes stained to imitate ebony. Pear leaves are more glossy than those of the apple; the blossoms appear earlier and are pure white, but like the apple blossoms, they are likely to be self-sterile. The fruit of most pear varieties is sweeter, more juicy, and less acid than that of apples. Groups of stone-cells (Fig. 299) are scattered among the parenchyma of the flesh.

Pears should be gathered before fully ripe. As in apples, there is great varietal difference in keeping quality, regional adaptation, and freedom from disease. The Bartlett (Fig. 300) is the standard, general purpose variety. Most pears do not stand cold storage as well as apples, though some kinds keep for several months.

Seeds of pears for propagation and also seedlings for budding have in years past been largely imported from France. Production of American grown stock has recently increased; in 1928 there were 9,195,000 pear seedlings grown in the United States. A federal plant-quarantine order, effective June 30, 1930, has prohibited imports of apple, pear, and Mazzard cherry stocks.

In soil and climatic adaptation, the pear is somewhat more restricted than the apple. In some regions well suited to it, particularly toward the southern portion of its range, the prevalence of fire-blight, a bacterial disease, is prohibitive to pear culture.

Commercially, the pear is a poor second to the apple among pomaceous fruits. American production rarely exceeds 25,000,000 bushels. The Far Western States afford more than half the pears of the union; California alone produces one third. Among Eastern States, New York leads; other production is widely scattered.

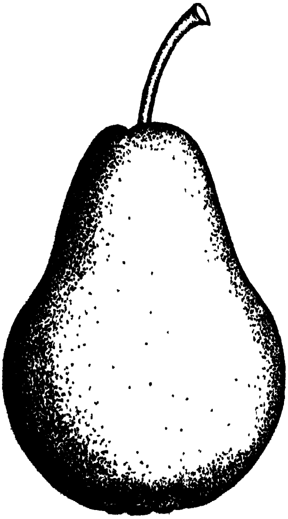

FIG. 300. — Pear (*Pyrus communis*), Bartlett Variety. (E. L. Spuller.)

Pears are principally used for eating fresh and for canning. A few are dried. Canada and the United Kingdom take about 85 per cent of American pear exports. Pears are a very popular fruit in Europe; large quantities are grown in France.

The Quince

Cydonia oblonga, the small shrubby tree which yields commercial quinces, is of Asiatic origin. While this fruit is available in most markets when in season, quinces are among the very minor American fruit products. The pome is large, and not particularly attractive in appearance. Unlike the apple and the pear, it does not soften sufficiently to be palatable raw, and is only used in jellies and preserves, often in mixture with apples. The quince plant grows slowly, is not particularly hardy, and is subject to fire-blight and insects.

Commercial quince culture is largely limited to California, Ohio, Pennsylvania, New York, and Ontario. In continental Europe, quince raising is relatively more important than in the United States.

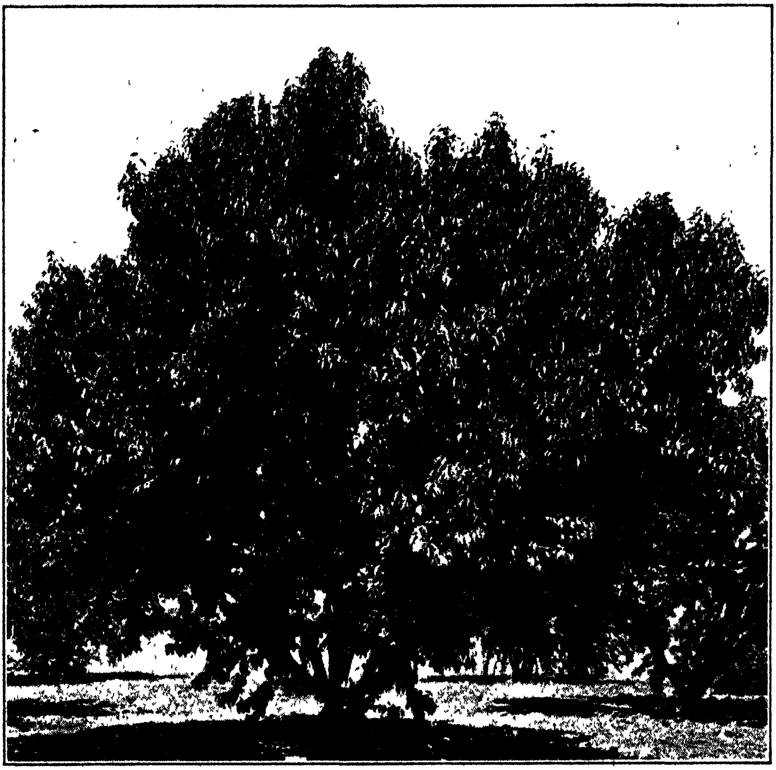

Fig. 301. — An Elberta Peach Tree, a Popular Yellow Fleshed Freestone Variety. (Courtesy of Division of Pomology, University of California.)

The Peach

THE PEACH TREE

Among hardy and semi-hardy fruits of the United States, the peach ranks second to the apple. It is the principal member of the Drupoideæ, or stone-fruit group, of the Rosaceæ. *Prunus* *persica* is a native of China. It is a small, rather low-growing tree (Fig. 301). As compared to the apple and pear, it is short lived, rarely attaining twenty years. Branches are slender and abundant. Leaves are numerous, long-lanceolate, and light green, appearing after the blossoms. Flowers are borne singly from the buds, which commonly occur in pairs at a node, with a leaf bud between (Fig. 302). They are bright pink and fragrant; a blooming peach orchard is one of the showiest of horticultural sights.

The flowers of the Drupoideæ differ from those of the Pomoideæ in that the tubular base of the calyx merely surrounds the pistil without becoming adnate to it. The ovary in the economic forms is one-celled; it often contains two ovules, but usually only one matures. The ripened fruit or DRUPE (Fig. 309) consists of three distinct regions: an outer thin tough epicarp, the "skin"; a juicy mesocarp; and a "stone" or endocarp of hard sclerified tissue, enveloping the single large seed. In all the Drupoideæ save the sweet almond, the seed is poisonous because of the presence of amygdalin.

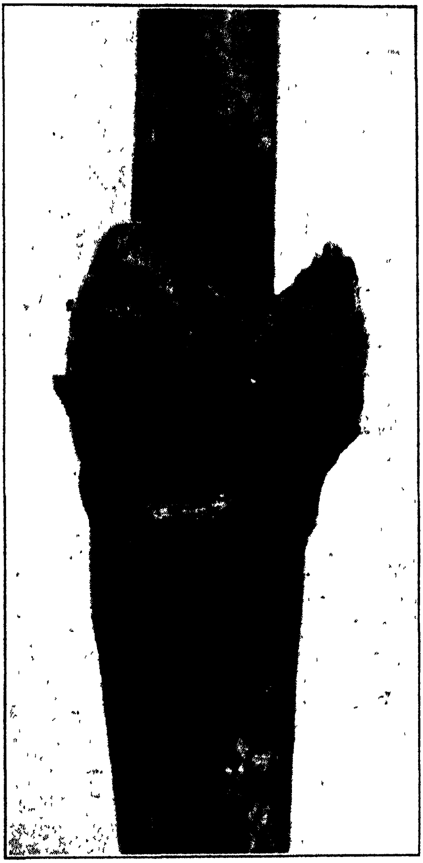

FIG. 302. — Peach Buds. The central leaf-bud is flanked on either side by a flower-bud. (Courtesy of Division of Pomology, University of California.)

The fruit of the peach (Fig. 303) reaches the largest size of any of the group, and, with the almond, is distinguished by its velvety epicarp. The endocarp is deeply pitted; in some forms, the clingstones, the mesocarp is closely adherent, while in freestone peaches the juicy portion readily separates when ripe.

Nectarines are smooth-skinned bud sports of the peach, of little importance.

ENVIRONMENTAL RELATIONS, DISTRIBUTION, AND VARIETIES

The peach is decidedly a tender tree. Temperatures of −15° to −20° F. are fairly certain to kill buds and quite likely to destroy or severely injure the tree. Early-blooming habit often brings damage from late frost. This tenderness decidedly limits the area of profitable peach culture and in many regions restricts it to special locations, such as "late" northern slopes, where vegetation may be retarded until frost danger is past. Few growing regions are damage-proof; peach crops, and therefore peach prices, are among the most variable in the whole fruit group.

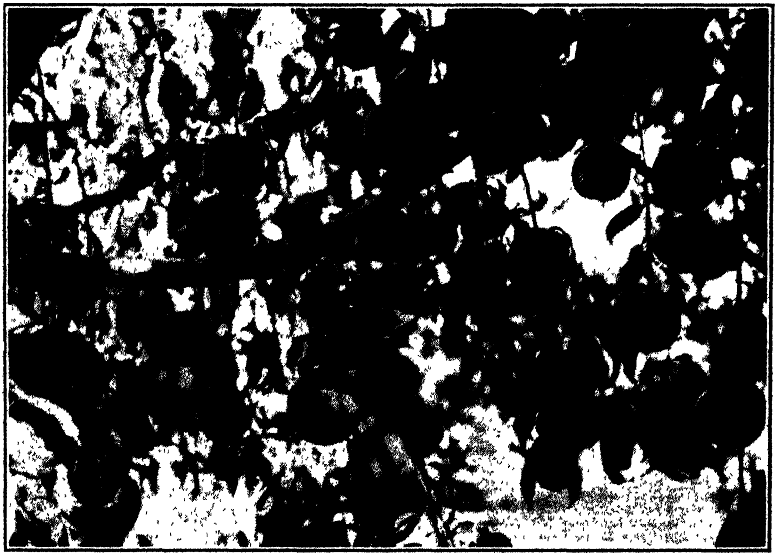

FIG. 303. — Fruiting Habit of the Peach. (Courtesy of Division of Pomology, University of California.)

Peaches are generally budded on seedling stock, which is grown from seeds of wild peaches naturalized in the hill-country of the Carolinas and Tennessee.

Distribution is shown in Fig. 304.

In 1931, peach production in the United States reached nearly 78,000,000 bushels. The crop is usually much less than this.

California usually affords one third or more of the peach production of the United States. Georgia ranks a poor second. Other peach growing regions are smaller and widely scattered.

Several races of the peach are recognized by systematists. Varietal groups, however, are known in the market mainly by color of flesh—white or yellow—and as cling-stones or freestones. Elberta is a standard yellow freestone, while the Tuscan is an example of a yellow cling. White varieties are comparatively unimportant.

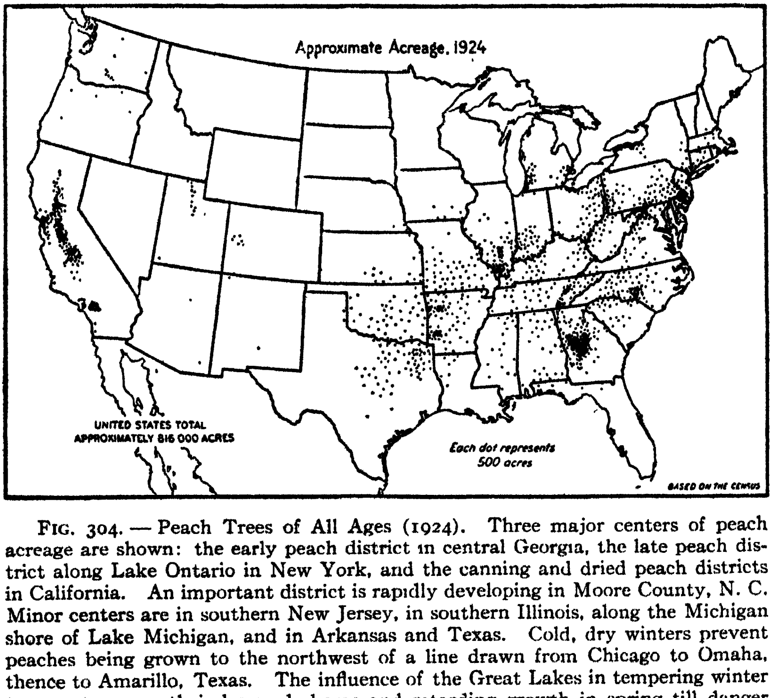
Approximate Acreage, 1924
UNITED STATES TOTAL APPROXIMATELY 816 000 ACRES
Each dot represents 500 acres
BASED ON THE CENSUS

FIG. 304. — Peach Trees of All Ages (1924). Three major centers of peach acreage are shown: the early peach district in central Georgia, the late peach district along Lake Ontario in New York, and the canning and dried peach districts in California. An important district is rapidly developing in Moore County, N. C. Minor centers are in southern New Jersey, in southern Illinois, along the Michigan shore of Lake Michigan, and in Arkansas and Texas. Cold, dry winters prevent peaches being grown to the northwest of a line drawn from Chicago to Omaha, thence to Amarillo, Texas. The influence of the Great Lakes in tempering winter temperatures on their leeward shores and retarding growth in spring till danger of frost is past is evident. (From United States Department of Agriculture *Yearbook*, 1928.)

USES OF THE PEACH

Peaches are used fresh, canned, and dried. The extremely perishable nature of the fruit precludes long storage and restricts distant shipment; the best dessert grades can be held in storage only about ten days. Drupaceous fruit, as a group, are highly perishable, both through natural deterioration and through liability to attack by brown rot. Thanks to varietal difference in ripening and the scattering of growing districts, peaches are available during the summer and early autumn season.

Fresh dessert peaches and those handled in the home are likely to be freestones, as are drying peaches. Because of distance from the large Eastern markets, the huge Californian production is chiefly in canning and drying peaches (Fig. 305). That State packs 95 per cent of America's canned peaches and practically all of the dried peaches. Canned peaches rank first among tinned fruit[1] in the United States and are an important export. Canning peaches are mostly large, yellow clingstones, handsome but hard-fleshed and almost inedible raw. Their firmness, in contrast with the softness of ripe, juicy freestones, withstands the bruises which quantity-handled fruit are certain to get, and they are delicious when cooked in sugar syrup.

FIG. 305. — Drying Peaches. (Courtesy of Division of Pomology, University of California.)

The California peach situation is a most striking instance of lack of coördination between production and present possibilities of distribution. In 1927, 2,708,000 bushels out of a total of 20,500,000 bushels, and in 1928, 2,917,000 bushels of 25,762,000 bushels, were abandoned on the trees for lack of profitable market. Loss to growers has been diminished by coöperative arrangement by which payment is received for peaches not marketed, and at least two years before the federal government adopted a similar plan of control for other crops bonuses were offered for destruction of peach trees. Smaller quantities, but as large in proportion to total output, are in some seasons wasted in Georgia. That State is carrying on promising experiments in the rapid-freezing of peaches (Fig. 306).

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[1] The term *fruit* is here used in its common-language and commercial sense; the tomato, which from the botanist's point of view is a fruit, exceeds the peach in bulk canned.

Among minor uses of peach-products may be mentioned the demand for the hard, compact pits for gas-mask charcoal during the World War, and the occasional use of the kernels in distilled and expressed "oil of almond."

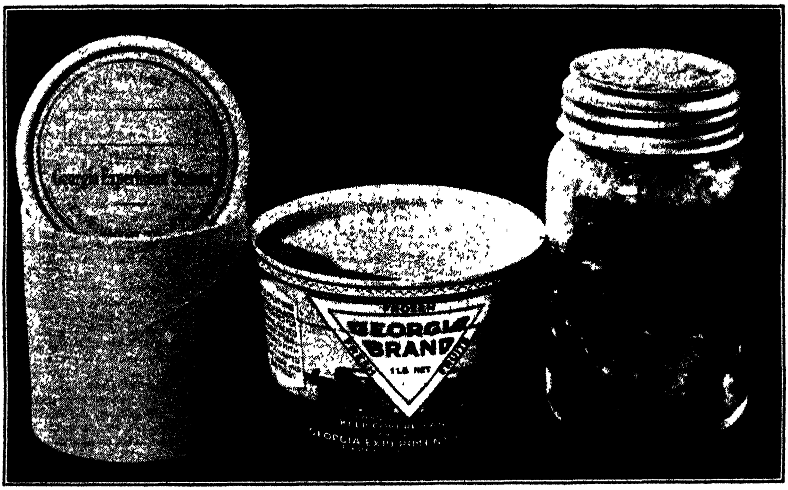

FIG. 306. — Peaches Frozen by Extreme-Cold Method, Illustrating Different Kinds of Containers. (Photo from Georgia Experiment Station.)

THE ALMOND

This product, which from a botanical point of view is a peach with a tough, inedible mesocarp, has been noticed among the nuts in Chapter XII.

The Apricot

Prunus Armeniaca, the Apricot, is of Chinese origin. The tree is larger and longer lived than the peach. Buds are often in threes, but less regularly so than in the peach. Flowers are light pink, appearing very early. Leaves are rounded-cordate often with attenuate apices. The fruit somewhat resembles a small, deep yellow peach, with smooth thin skin and smooth, easily separable stone.

In the West, apricots are usually budded on apricot stock, but in the East peach or Myrobalan Plum (*Prunus cerasifera*) are used.

In temperature relations apricots resemble the peach, but because of their even earlier blooming their profitable range of cultivation is less. They are grown on a small scale in many peach regions, but their commercial production is almost wholly Western. Ninety-five per cent of the American crop comes from California; there are productive areas also in the Rocky Mountain region. In 1928, there were 368,000,000 pounds of apricots grown in California.

Apricots are eaten fresh, cooked or canned, and dried. Like most stone fruits, they store poorly. Between 35,000,000 and 50,000,000 pounds of apricots are dried annually in California. Less than 20 per cent of the crop is canned or otherwise preserved without drying.

Spain and Argentina are important foreign producers of apricots. We import about 1,000,000 pounds of canned apricots annually from Spain.

The Plums and Prunes

The term plum is applied to a considerable number of *Prunus* species with large, edible fruit. Prunes are plums which will dry whole without souring. Plums of cultivation are of three groups, the DOMESTICA, the JAPANESE, and the AMERICANA.

The Domestica or European plums are by far the most important group. They are derived from *Prunus domestica* of the Caucasus region, a medium-sized tree which has been in cultivation 2,000 years or more. Prunes are large, solid Domestica varieties. The Green Gage, Damson, and Egg plums, as well as numerous other varieties, belong here.

The Japanese Plums are derivatives of the Oriental *P. salicina*. They were first brought into American cultivation about 1870. In the 1880's and later, many varieties were imported or developed by Luther Burbank, whose name identifies one of the most popular kinds. Others are Abundance, Satsuma, and Red June.

The Americana group includes a variety of native species and their hybrids.

Plums are of sufficient variety to provide kinds for almost the entire cultivable United States. They include plants of rather diverse aspect, mostly medium to small trees with few to many buds on stiff spurs. Most plums have a tendency toward thorniness. The Domestica form the largest trees; they are widely cultivated, and of special importance on the Pacific Coast. Though Japanese kinds are of wide American range and considerable popularity, they appear to be little grown in the Orient or elsewhere. Americanas are of interior and southern distribution.

Large-scale plum growing is confined to the extreme West. California produces about 60 per cent of the commercial crop, of which the bulk is prunes. Idaho, Oregon, and Washington furnish 30 per cent, nearly all prunes. Commercial plums elsewhere are chiefly in New York, Georgia, and a few other States.

Some kinds of plums, including most of the Americanas, are unpalatable raw, and are consumed mainly in preserves and marmalades. European types are used as fresh fruit and for canning; these also include the prunes. The term PRUNE is used commercially only for the dried product; fresh fruit of prune varieties is sold as plums. French or sweet prunes are grown in California, while those of the Pacific Northwest are of the more acid Italian type (Fig. 307). All prunes, acid or not, contain a high percentage of sugar.

PREPARATION OF PRUNES

The ripe fruit is first carefully cleaned and the skins are broken to facilitate drying. Both processes may be accomplished at once by dipping in hot water or hot lye. California prunes are dried in the open sun (Fig. 308); those of more humid Oregon, Washington, and Idaho by artificial heat. After drying they are allowed to "sweat" for two or three weeks; then gloss is imparted by heating in steam, boiling water, fruit juice, or glycerine. This scalding of the surface destroys insect eggs and larvæ which might otherwise develop in storage.

The prune crop, wherever grown, is subject to great fluctuation. Domestic production averages about 300,000,000 pounds a year, of which large quantities are exported. Of a "bumper crop" of 406,000,000 pounds in 1927, over 60 per cent went abroad, chiefly to Northern Europe.

Jugoslavia and France are the largest foreign producers of prunes. The flavor of Jugoslavian prunes is midway between that of the sweet French and the tart Italian kinds. The Jugoslavian output has been as high as 170,000,000 pounds in a year. The French industry is much smaller and is declining.

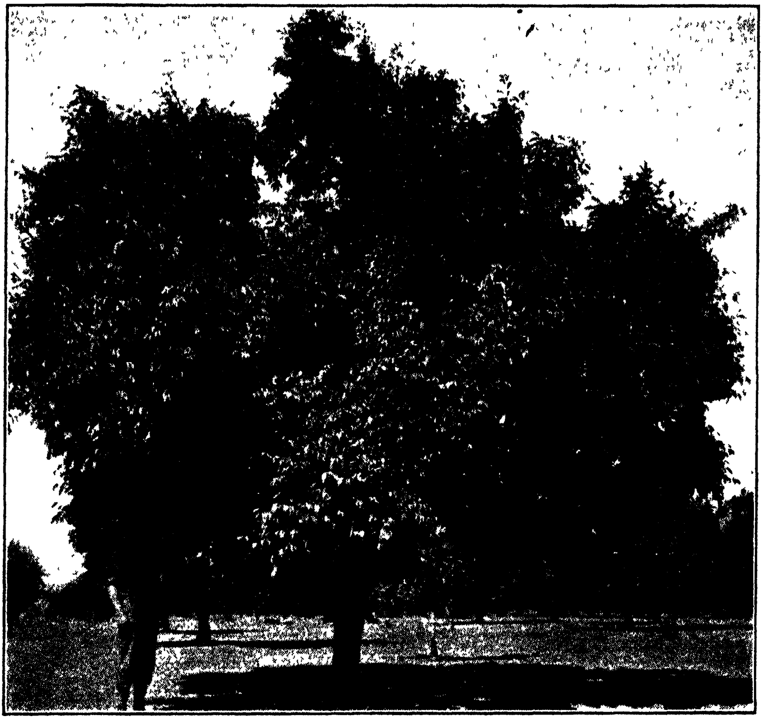

FIG. 307. — An Italian Prune Tree in Oregon. (Courtesy of Bureau of Plant Industry.)

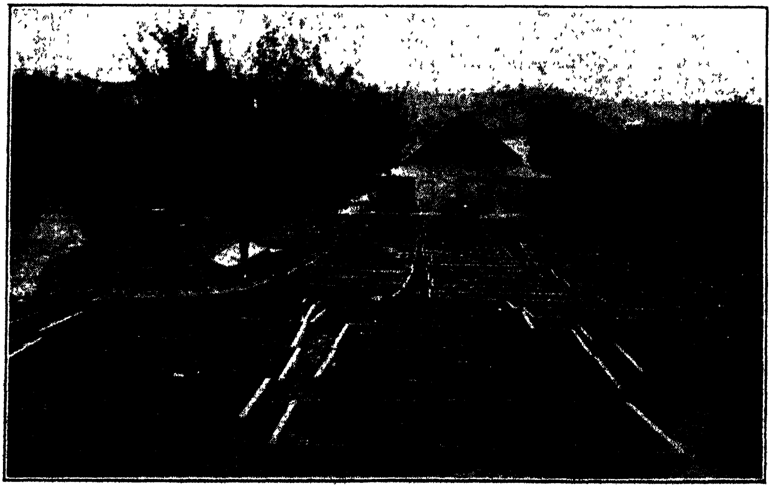

FIG. 308. — A Prune Drying-Yard in Central California. (Courtesy of Bureau of Plant Industry.)

The Cherries

Cultivated cherries (Fig. 309) are of two principal kinds, the Sweet Cherry, from *Prunus avium,* and the Sour Cherry, from *P. Cerasus.* Both are of European origin. The sweet cherry is a large, long-lived tree of somewhat excurrent aspect, with gray-brown bark whose outer layers peel in a rather birchlike fashion. The sour cherry is a smaller, round-headed tree. The flowers of both are borne in small umbels, appearing with or before the leaves. A race intermediate between *Prunus Cerasus* and *P. avium* is represented by the Duke Cherry.

Sweet cherries have about the same climatic limitations as the peach. They are chiefly grown in the Great Lake region and the Pacific Coast, whereas the largest sour cherry production is in New York, Wisconsin, and Michigan.

Sour cherries are budded on Mahaleb (*Prunus Mahaleb*) stock, or else on a form of the sweet cherry known as the Mazzard. The latter is also mostly used for sweet cherry budding.

Yields of all sorts of cherries are much affected by climatic conditions.

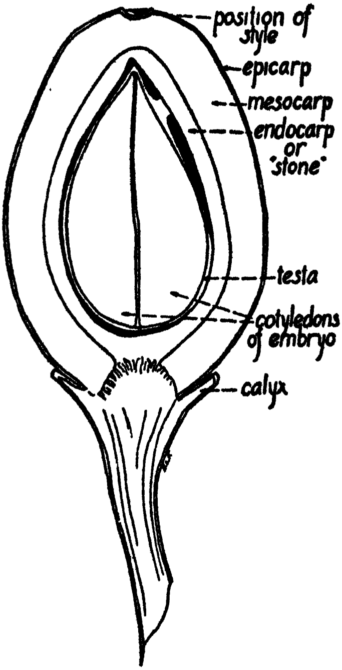

FIG. 309. — Median Longitudinal Section of the Immature Drupe of a Cherry (*Prunus*). (From Robbins, *Botany of Crop Plants,* P. Blakiston's Son & Co., Inc.)

Varieties and Uses.—Cherries of all kinds are noted "pie timber" and much used for canning. Sweet cherries are eaten fresh, but sour kinds are too acid for most tastes. Royal Anne, a large yellow red-flushed sweet cherry, forms about 40 per cent of the Pacific Coast crop. Large quantities of Royal Annes are sulphured and brined for preservation. In this process the fresh fruit is exposed to fumes of burning sulphur, which bleaches the skin to straw-color. After this it is barrelled in brine to which sodium sulphite is added. This treatment hardens the naturally soft flesh of the cherry. Glacé and Maraschino cherries are made from fruit so preserved. The former are thoroughly syrup-saturated and drained. Maraschino cherries are artificially colored bright red. Both are used in confections, desserts, and salads.

Several favorite sweet cherries are rich deep red. Among these are Black Tartarian and Bing.

Sour cherries are bright red, smaller than sweet varieties, and mostly used for canning and cooking. Montmorency is a favorite variety.

Cherry growing is an important industry of southern Europe. Italy leads; about 100,000 barrels of sulphured and brined cherries are exported annually to the United States. Maraschino and glacé cherries are imported from France.

The Strawberry

Edible fruits of the Rosoideæ consist of numerous achenes (strawberry) or drupelets (blackberry, raspberry, etc.) borne on an enlarged common receptacle, whose proportions and character vary in the different kinds. Among these fruits, the strawberry is preëminent.

The ordinary cultivated strawberry is a derivative of *Fragaria chiloensis* of western South America, probably somewhat hybridized with *F. virginiana*, the small Eastern American Wild Strawberry. Perpetual and Everbearing Strawberries are from *F. vesca*, the European Wild Strawberry.

THE STRAWBERRY PLANT

This is a low semi-evergreen perennial with a short thick stem or crown partly above, partly below, the ground and sheathed with leaf-bases. The roots are wiry-fibrous. Leaves are long-petioled, trifoliate, with leaflets serrate on their outer exposures and plane on adjacent edges.

Flowers are white-petaled, the petals soon shed. In a few varieties stamens are scant in number or missing. Perfect flowers, which are borne by most cultivated varieties, possess numerous conspicuous yellow anthered stamens surrounding the domed center of the receptacle with its numerous achenes. Stamens mature before pistils; cross pollination is by insects.

The corymbose flower clusters are borne on long slender peduncles; there is often a considerable interval of ripening in the cluster. The nature of the ripened fruit is shown in Fig. 310.

Strawberries are propagated by runners—slender vegetative branches which extend along the ground, producing roots, a new crown, and leaves at successive nodes. *Fragaria chiloensis*

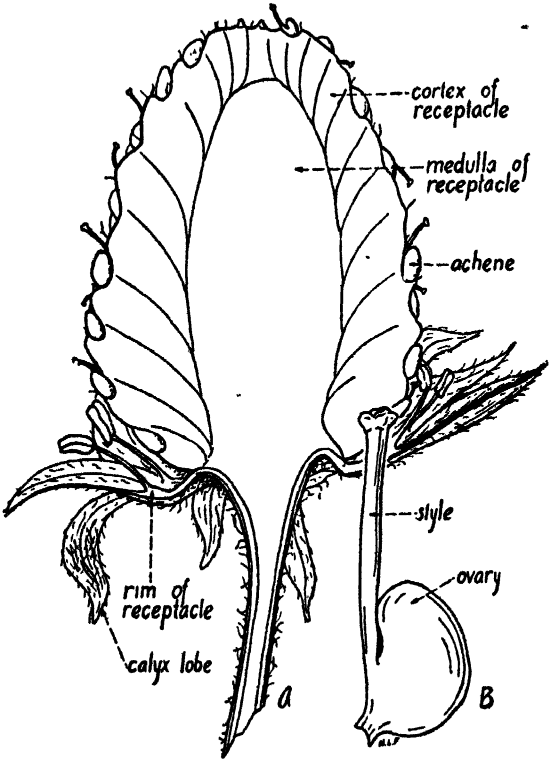

FIG. 310. — *A*, Strawberry (*Fragaria*) in Median Longitudinal Section. The mass of the "fruit" is made up of modified stem-tissue (receptacle), on which are the true fruits or achenes. *B*, single achene, enlarged. (From Robbins, *Botany of Crop Plants*, P. Blakiston's Son & Co., Inc.)

usually produces runners after the fruiting season; *F. virginiana* before. A strawberry plant may produce several runners and each runner, several plants. In strawberry culture the majority of runner-plants have to be treated as weeds, else the field will become a tangle of plants, choked and unprofitable from mutual competition. Under field conditions, seed rarely germinate.

CULTURE AND DISTRIBUTION OF THE STRAWBERRY

Commercial strawberry culture began about 1800. Its active development dates from about 1860. A recent author[1] summarizes the present importance of the crop as follows:

> "Strawberries constitute one of the most widely grown fruit crops of the United States. They can be grown successfully in all latitudes of the country and are the first deciduous fruit to mature each season in the localities in which they are grown. Strawberries are available on the larger markets for practically nine months of each year. Although the total crop of strawberries in the United States could be produced on less acreage than the land area of an average county, the labor and money expended in details of production, harvesting, and marketing, approximate an estimated value of more than $44,000,000 annually. . . .
>
> "The production of strawberries is classed among the leading truck-crop industries of the United States. The estimated value of the market-strawberry crops of the country averaged $44,128,000 for the three years ended with 1926. During this period the crop was fifth among the fruit crops of the country in total farm cash value, and in gross returns to the growers it was exceeded only by apples, oranges, grapes, and peaches in the order named."

Most of the strawberry crop is produced in small patches and fields of not more than a few acres. The distribution and periodicity of bearing of the principal strawberry areas is shown in Fig. 311.

> "Practically two-thirds of the market production is confined to a few large centralized shipping districts. These include the Eastern Shore district,[2] the Norfolk section of Virginia, and the Carolina district, all situated in the Atlantic Coast area; Florida, Louisiana, Mississippi, Alabama, and Texas in the Gulf area; Tennessee, Kentucky, southern Illinois, and Indiana in the east-central area; and the Ozark[3] and the White County[4] districts in the west-central area.
>
> "The Pacific-coast area includes California, Washington, and Oregon. These States form a self-sustaining strawberry industry inasmuch as they produce and consume in the fresh state or preserve practically all stock handled in the home territory.
>
> "Michigan, New York, Wisconsin, Pennsylvania, Ohio, and Iowa each have small acreages that produce minor quantities for carload

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[1] J. W. Strowbridge, "Origin and Distribution of the Commercial Strawberry Crop," United States Department of Agriculture, *Technical Bulletin 180*, May, 1930.

[2] Author's footnote: Includes Delaware, and those parts of Maryland and Virginia situated on the peninsula that lies east of Chesapeake Bay.

[3] Author's footnote: Includes parts of Missouri, Arkansas, and Oklahoma.

[4] Author's footnote: Includes White County, Ark., and vicinity.

distribution. Maine and Montana have small acreages that produce late crops, from which the last carload shipments of the season are made. . . .

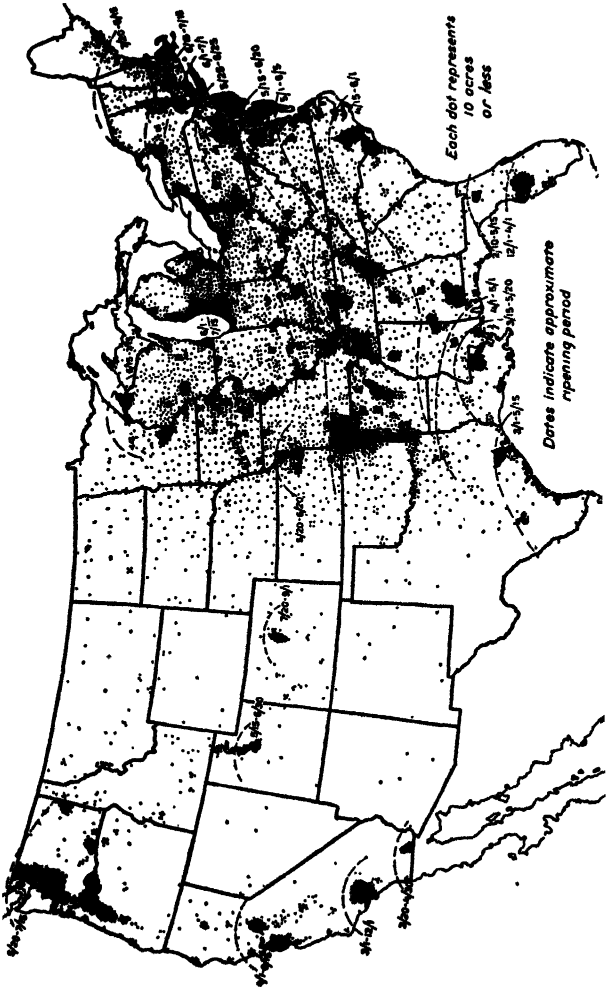
Each dot represents 10 acres or less
Dates indicate approximate ripening period

FIG. 311. — Acreage of Strawberries, 1924. Acreage of all counties in the United States that reported the cultivation of strawberries during 1924 is indicated by dots on this map. (1925 Census and Division of Crop and Livestock Estimates report.) The sections south of each date line are included in the harvesting period indicated by date given. (From Strowbridge, Technical Bulletin 180, United States Department of Agriculture.)

"Tennessee, which averaged 17,744 acres per year during the period 1920–1926, leads the States in strawberry acreage; Arkansas, with an average of 15,499 acres, is second."[5]

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[5] Strowbridge, *loc. cit.*

While strawberries afford varieties of considerable spread of season in all localities, States south of the thirty-fourth parallel furnish the early commercial crop, those between the thirty-fourth and fortieth the second-early and intermediate, and those north of the fortieth the late crop. About 50 per cent of the entire crop is harvested in June.

Strawberries are picked when nearly or quite ripe. They are one of the most perishable of crops and are usually not moved far to market.

USES OF THE STRAWBERRY

The strawberry is preëminently a fresh dessert fruit. Increasing quantities are being utilized in preserves, jams, ice creams for soda-fountain purposes, etc. About 55 per cent of commercial fruit preserves are strawberries. The preserving industry is of special importance on the Pacific coast. Large acreages in California, Oregon, and Washington are remote from the major markets; their fruit is frozen and shipped to preserving establishments. Shipment of frozen fruit for preserving seems destined rapidly to increase, and new methods of extreme cold freezing are likely to extend utilization to dessert fruit.

Blackberries, Raspberries, and Loganberries

These are all cane or bramble fruits of the genus *Rubus*. The thorny stems are large-pithed, semi-woody, and biennial, bearing fruit the second year. Blackberries are of several native species whose wild representatives (Fig. 312) are found in abundance in cut-over woodlands of the Appalachian region. Some forms, known as dewberries, are trailing vines, rooting at the tips, grown on wires and trellises. Dewberries ripen early but are not of high quality. Blackberries proper are stout, very thorny[6] upright plants with fluted stems in dense clusters from the rather woody underground system. They are propagated by root-suckers and root cuttings. The loganberry is a red-fruited trailing type, originating on the Pacific coast and long reputed a hybrid between raspberry and blackberry. It is now considered a form or mutant of the blackberry.

Fruit of all these are clusters of juicy drupelets on a soft receptacle, velvety black save for the loganberry and occasional pale or "white" forms which are not of much commercial significance.

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[6] Thornless sports exist.

Blackberry varieties differ much in hardiness. They winterkill in the Northern and Plains States and suffer from the aridity of the Southwest. Commercial culture is mainly in the Pacific Coast States and in Michigan, Texas, and Maryland.

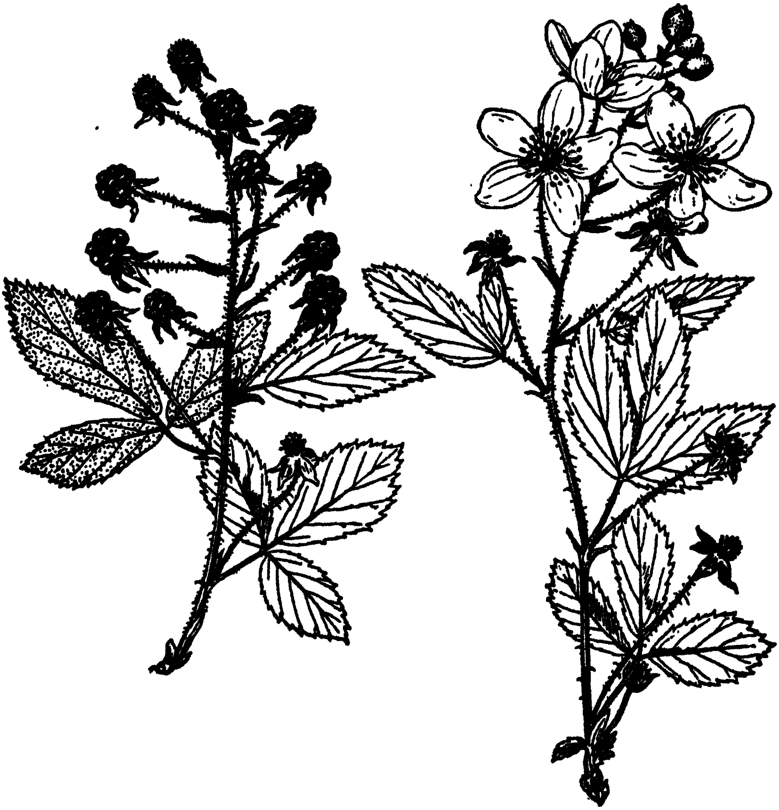

FIG. 312. — A Natural Blackberry Hybrid of New England (*Rubus allegheniensis* X *argutus*). This has been cited as the probable progenitor of several valuable cultivated varieties. (From Brainerd and Peitersen, *Blackberries of New England*, Vermont Agricultural Experiment Station Bulletin, 217.)

Raspberries are of three groups, the REDS (Fig. 313), from the European *Rubus idaeus* and its variety *strigosus* of the United States and Canada; BLACKS or BLACKCAPS (Fig. 314) from the native *R. occidentalis*, and the PURPLES or Purple-canes, hybrids between Reds and Blacks.

Red raspberries are of vigorous upright growth, prickly rather than stoutly thorned like the blackberries. They are propa-

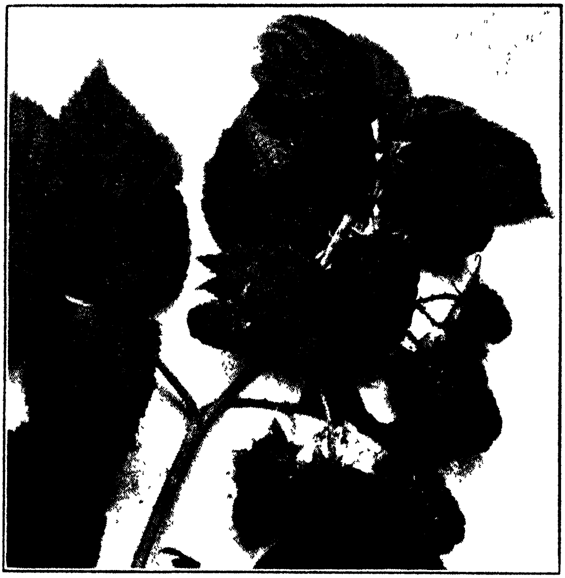

FIG. 313 — A Red Raspberry. (Courtesy of New York Agricultural Experiment Station)

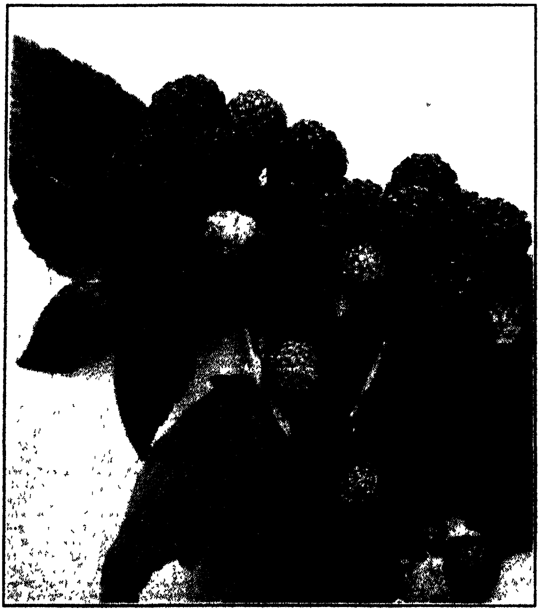

FIG. 314. — A Black Raspberry. (Courtesy of New York Agricultural Experiment Station.)

gated from suckers. Canes of blacks and purples are of spreading, arching growth, turning down during summer and rooting at the tips. Red raspberries can be grown in the Northern States and in Canada, while the blacks and purple-canes are less hardy. All raspberries are intolerant of heat and drought.

The receptacle or hypanthium of raspberries is hard and woody; it remains on the cane, while the ripened drupelets separate in thimblelike form.

The cultivated *Rubus* species are mostly grown in small patches in home gardens or as part of a diversified fruit culture.

Blackberries, dewberries, and red raspberries are largely used fresh; they also enter into preserves and jams. Loganberries are extremely acid and are chiefly utilized in cooked forms and in fruit juices. Blackcaps are largely dried, while the fruit of purple-canes finds chief outlet in preserves.

About 24 per cent of America's commercial fruit pack is of raspberries.

2. Citrus Fruits

This valuable group of fruits is derived from various species of *Citrus* of the Rutaceæ, all natives of the Old World. The principal species are cultivated on a most extensive scale in California and Florida.

The Citrus Species

Citrus species are small or medium-sized trees with hard, dense wood. All save one species, the inedible Trifoliate Orange (*Citrus trifoliata*) are evergreen. They vary much in hardiness, from the lime, which is quite intolerant of frost, to the trifoliate orange, which can be grown outdoors as far north as New York. Commercial culture is profitable only in tropical or subtropical regions; that of the orange and grapefruit has reached its greatest development in regions not wholly frost-free.

Citrus root systems lack root-hairs; absorption is facilitated by their association with fungi in the soil. This fact renders special precautions necessary in transplanting. Orchard trees are of rounded columnar or spherical form, headed low to facilitate picking. Most species produce axillary thorns. Leaves are glabrous or glaucous and bright green, dotted with oil-glands like the rind of the fruit. Glands also occur in the margins. The leaves appear simple, but the presence of a joint between the broad terminal blade and the narrow-winged petiole indicates that the structure is derived from a compound form whose basal leaflets have been reduced and modified almost out of existence.

Citrus flowers are white or purplish-pink, solitary or in small clusters. The calyx is three- to six-toothed; petals vary from four to eight. Stamens are numerous, in several groups. The ovary is many-celled, the compartments corresponding to the number of sections in the fruit. The flowers are extremely fragrant; several kinds are used in perfume manufacture. They are ordinarily cross-pollinated; navel oranges and some other seedless citrus varieties set fruit without fertilization. The familiar fruit varies in proportion and appearance with species and variety. Technically it is a sort of modified berry known as a hesperidium. The thick, semi-leathery rind is believed to be derived from union of modified leaves surrounding the carpels; the puckered tissue at the apical end of a naval orange is a secondary row of undeveloped carpels. Seeds are usually several in a carpel. They are peculiar in having two or more embryos; one arises from normal fertilization and the rest from a sort of budding of the nucellus tissues. The former present characteristics from two parents, while the latter, arising by vegetative division in asexual manner, "come true," or reproduce the plant which bore the seed.

The Orange

The principal orange cultivated for fruit is known as *Citrus sinensis* or *C. Aurantium* var. *sinensis* (Fig. 315). As the scientific name indicates, it is probably of Chinese origin. It is said to have been introduced to Europe by the Moors in Spain and perhaps independently by early Portuguese navigators. For some centuries the Mediterranean region was the chief orange country of the world, and even now the output of Spain and Italy probably equals that of the United States in quantity, though hardly in quality.

Some orange varieties, such as Tangerine, Satsuma, and King, are from *Citrus nobilis.*

DEVELOPMENT OF THE AMERICAN ORANGE INDUSTRY

The history of orange growing in the United States is a history of climatic vicissitudes and insect and disease attack. Large-scale production developed first in Florida. In 1894 that State produced 4,000,000 boxes of oranges. In December, and in February of 1895, came disastrous frosts, reaching 14° F.

in northern Florida. All along the south Atlantic seaboard the orange crop was ruined and the trees severely injured. Only 75,000 boxes of Florida oranges were shipped in 1895. That the citrus industry was ever reëstablished is due very largely to the fact that, both in Florida and in California, it has been mainly financed by wealthy business men who carried it on as much from the amateur or sporting viewpoint as from hope of profit. Where an ordinary agriculturalist would have been both literally and figuratively frozen out, these men were not discouraged by a succession of profitless years. They were able to finance, furthermore, expensive experimental and trial-and-error methods which were necessary to develop citrus produc-

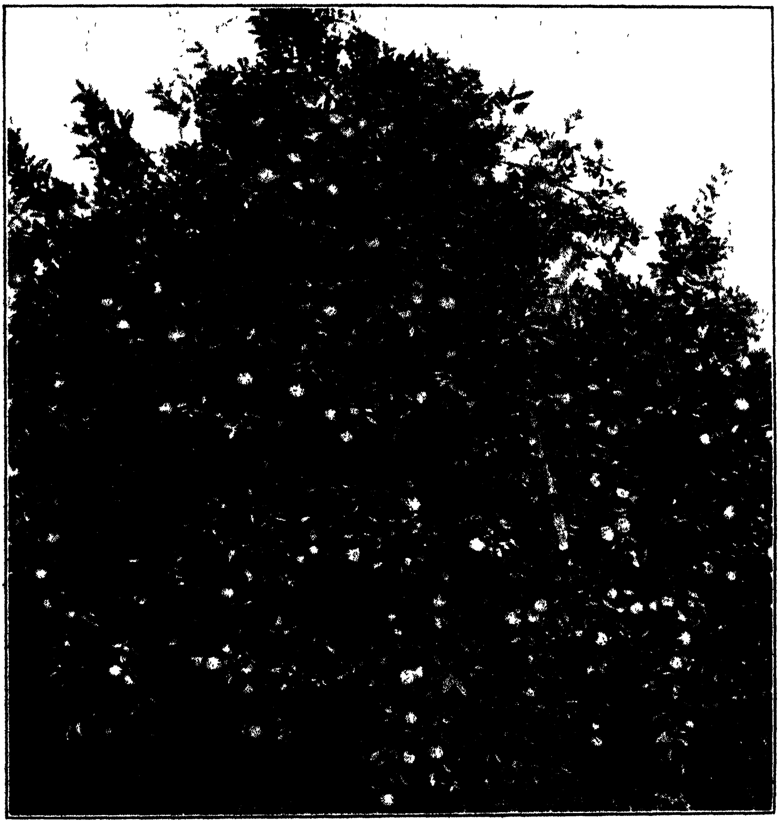

FIG. 315. — An Eight-Year-Old Washington Navel Orange at Riverside, California. (Courtesy of Bureau of Plant Industry.)

tion in Florida and California. Their general business experience, moreover, pointed the way to the coöperation in handling and marketing which has been the vital factor in the success of California orange culture.

THE MEDITERRANEAN FRUIT FLY

Florida orange culture has been in more recent years handicapped by the citrus canker, a disastrous bacterial disease against which a most vigorous campaign has been waged, and by the Mediterranean fruit fly, which appeared in that State in April, 1929, and which, it was soon discovered, was scattered in nearly 1,000 different localities throughout twenty counties. This fly is held to be the worst fruit pest known, attacking not only the orange, but nearly all other market fruits and many vegetables. Watermelons, pineapples, strawberries, lemons, and sour limes are said to be among the few fruits exempt.

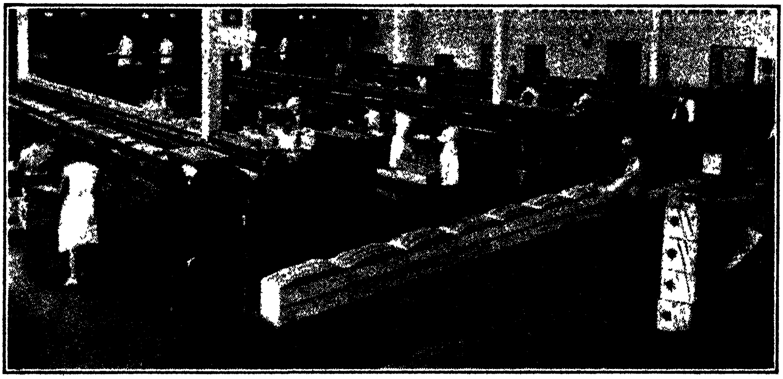

FIG. 316. — An Orange-Packing House. (Courtesy of Bureau of Plant Industry.)

Discovery of this menace resulted in one of the most intensive insect eradication campaigns in all agricultural history.[7] Operations covered over 8,100,000 acres, a region which contained about 67 per cent of the bearing citrus trees of Florida, and which had produced 76 per cent of the three-year average of citrus shipments. This large territory was thoroughly quarantined. While more than three fourths of Florida's fruit crop had been marketed before the fly was discovered, over 580,000 boxes of citrus fruit and large quantities of other produce were destroyed because they had been raised in infested regions or within a mile of them. Transportation of Florida fruits and vegetables to other States was stopped.

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[7] For a more complete account of this campaign see United States Department of Agriculture *Yearbook* for 1930, pp. 50–55.

In order to destroy flies and to prevent their migration from infested zones, hosts of all sorts in any state of growth which might harbor the fly were eliminated during the summer, and poisoned baits were spread. Oranges and other fruits were taken from the trees and destroyed. Experiments presently indicated that insects within infested fruit could be killed by chilling the product to 28° Fahrenheit or heating it to 110°—findings which later obviated the destruction of much valuable material. Among many interesting experimental results of research in fruit-fly eradication was a method of amplifying to audibility the sounds of the larvæ invisible within the fruit.

As a result of a most intensive campaign, Florida, in 1931, was declared presumptively free from the Mediterranean fruit fly, but careful watch will continue to be maintained for any insects which may have escaped.

CALIFORNIAN DIFFICULTIES

Disease and insect difficulty in California has been less than in Florida, thanks, no doubt, in large part to the geographical isolation of California from other great agricultural regions and also to efficiently maintained quarantines. Scale insects are a nuisance. Frost is an annual hazard. A serious freeze occurred in 1913. Raising air-humidity by irrigation, laying down smoke- or smudge-blankets, and the use of various types of orchard heaters (Fig. 317) have been fairly efficacious in preventing frost loss unless the temperature goes somewhat below 28° Fahrenheit and remains there for some hours.

KINDS OF ORANGES

Oranges grown in Florida and California are of somewhat different types. The popular fruit of Florida are medium-sized light yellow or russeted oranges, decidedly sweet and comparatively thin-skinned. Oranges for shipment are picked in a somewhat unripe state. The underlying yellow may be brought out by destroying the chlorophyll by gases of gasoline combustion or by ethylene. Not only are "green" oranges treated this way; the early and comparatively hardy Satsuma orange (*Citrus nobilis* var. *unshiu*) is green and unattractive when first ripe, but is readily "gassed" into a bright orange-color.

Florida oranges ripen mainly in the early winter.

The chief Californian orange is the Washington Navel (Fig. 315) of which several varieties are in cultivation. This seedless variety originated in Brazil. In that humid climate it is not of especially high quality and is not considered a shipping orange. In the arid, semi-tropical region of southern California it has become "the greatest commercial orange in the world." It is the largest of the common oranges; the skin is bright-orange, deeply gland-dotted, rather thick and coarse. The pulp is of sparkling acidity. Navels are in season from the northern and central regions of the orange belt in November and December; from December to June in the principal orange country of the southern portion of the State.

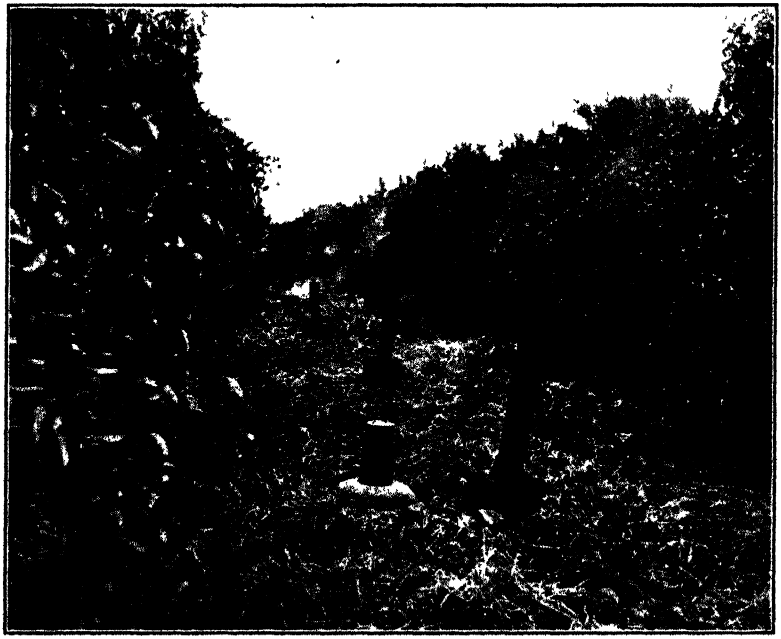

FIG. 317. — Oil-Burning Heaters in a California Orange Grove. (Courtesy of California Fruit Growers' Exchange.)

The Valencia, or "Summer Orange," constitutes the other principal orange crop of California. Valencias also are bright-orange; spherical, lacking the navel, and seed-bearing. They ripen from June to October, and thus are in the market when other oranges are scarce.

Oranges "hang" on the tree without deterioration for some time—a factor of some advantage in marketing.

Small quantities of oranges are grown in Louisiana, Texas, and Arizona.

The Bitter Orange.—Citrus Aurantium, or *Citrus Aurantium* var. *amara,* the Sour or Bitter Orange, is grown in North America chiefly as an ornamental and as a stock for the grafting of other citrus fruit. The fruit is very large, but acid-bitter and useful only to a limited extent in orangeade and in marmalade. The rind has a minor use in medicine.

The Grapefruit

The Grapefruit, *Citrus grandis,* also known as *C. paradisi,* ranks second to the orange in American citrus culture. Its history is somewhat obscure. *Citrus grandis,* or *C. maxima,* the Shaddock, is a large bitter-fruited tree of Malaysia, which was introduced into the West Indies by a navigator named Shaddock. The grapefruit has been considered a variety of this. There is evidence that it originated as a seedling sport in the West Indies and was introduced into the United States about 1809.

The grapefruit forms a vigorous tree, coming into bearing at a very early age (Fig. 318). The whiplike branches of trees, scarce the height of a man, bend to the ground with great clusters of the huge fruit. This clustering characteristic is probably responsible for the name "grapefruit."

The hesperidium is the largest of the edible citrus group, flattened-spheroidal, light yellow or russeted, with inconspicuous oil-glands. Seeds are usually numerous, though constant attempt to eliminate them has succeeded in part. There are seedless varieties—bud-sports whose progeny have a tendency to revert to the seeded type.

The grapefruit is somewhat more frost-hardy than the orange. American production is mostly localized in Florida. There, early culture was extremely profitable. Spasmodic interest has been manifested in grapefruit in California, especially after the Florida frosts of 1894–1895. Results were not particularly satisfactory, and much of the acreage was top-worked to oranges. In the development of the near-tropical Imperial Valley of southern California considerable acreages of grapefruit have been set. Arizona and Texas also market grapefruit.

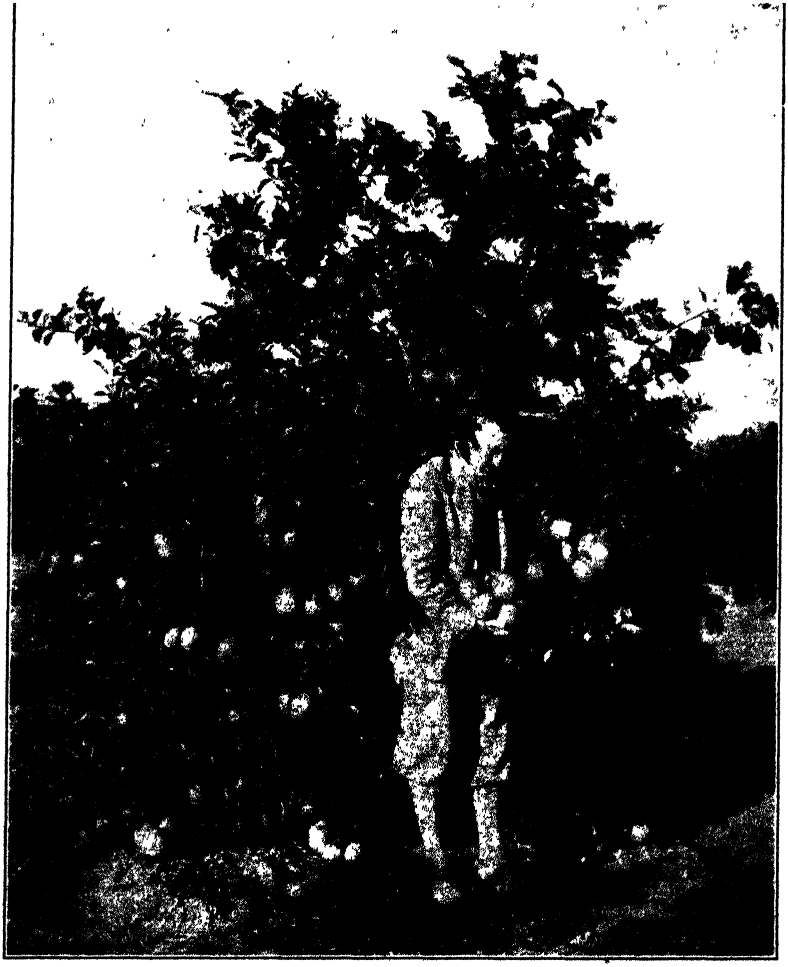

FIG. 318. — A Marsh Grapefruit Tree at Phoenix, Arizona, Four Years after Planting. (Courtesy of Bureau of Plant Industry.)

In years past grapefruit have been chiefly used as breakfast fruit and in fruit salads. The grapefruit is, practically, the only citrus fruit seen in cans, and canning and preparation of grapefruit juice is increasing.

The Lemon

The Lemon, *Citrus Limonia* (Fig. 319), is the principal strongly acid citrus fruit. The plant is a small short-spiny tree of Asiatic origin; in culture it is usually budded on the sour orange or the rough lemon (Fig. 320).

The lemon is less hardy than the orange and therefore is no longer extensively grown in Florida. Commercial lemon production in the United States is confined to California, where the tree was introduced by early Spanish missionaries. Here best results are obtained in frost-free localities of the southern coast regions where summer temperatures are not inordinately high. Californian success has been attained only after many years of expensive disappointment.

FIG. 319. — Flowers and Fruit of the Lemon (*Citrus Limonia*). (Courtesy of California Fruit Growers' Exchange.)

Lemons ripen throughout the year. While tree-ripened oranges are superior, tree-ripened lemons are dry, over-sized, and bitter. High-grade lemons are picked when they reach a diameter of $2^5/_{16}$ inches in winter and $2\frac{1}{2}$ inches in summer. Size is ascertained by slipping a ring over the fruit. Orchards are picked every month or six weeks. Lemons are cured and ripened in various ways, often simply by piling under a thin covering of straw beneath the trees. In large orchards the process is more elaborate; lemons are stored in well-ventilated basements or curing rooms in which humidity and temperature are carefully regulated. Properly cured lemons, picked in November and December, may keep until the following summer. Curing may be speeded by oil-stove vapors or ethylene.

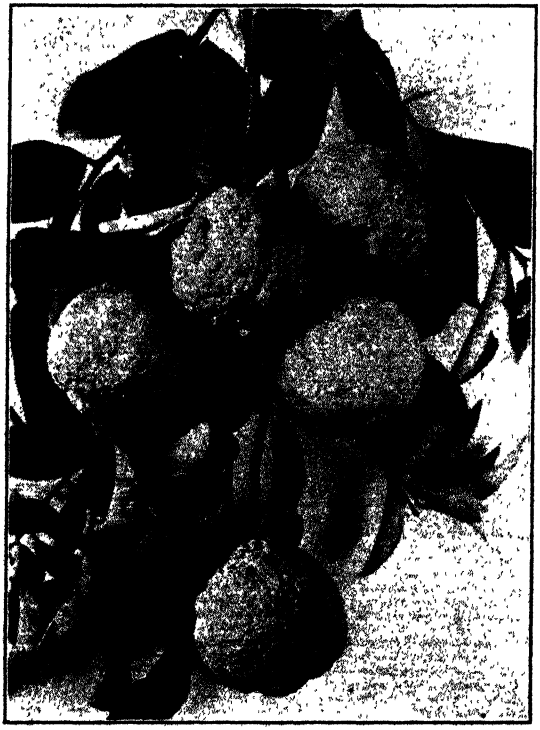

FIG. 320. — Fruit and Foliage of the Rough Lemon (*Citrus Limonia*). This is a vigorous and resistant plant used as a stock on which to bud oranges and ordinary lemons. (Courtesy of Florida Experiment Station.)

Other Citrus Fruits

The Lime (*Citrus aurantifolia*) is even less hardy than the lemon and is cultivated only in frost-free regions of the tropics, extreme southern Florida, and as a garden fruit in California. Lime trees are very thorny. The fruit of the most common type, the sour lime, which is produced mostly in the summer, resembles a small, extremely acid lemon.

The CITRON (*Citrus medica*) is not much grown in this country. The fruit is somewhat like a huge lemon. Only the rind is used; this is candied in sugar-syrup and is used in cakes of the richer, heavier sort.

The BERGAMOT (*Citrus Bergamia*) is likewise rarely seen with us. It is chiefly grown in southern Europe, for its volatile oil and perfume. The oil is sometimes used as a clearing agent in microtechnique.

The KUMQUATS are species of *Fortunella*, closely related to *Citrus*. They are small trees or shrubs, with numerous small bright-orange fruit. Kumquats are chiefly grown for ornament, although the fruits may be used in preserves.

CITRUS HYBRIDS

Citrus species hybridize readily. Of a considerable number of experimental hybrids, some show commercial promise. Among these is the CITRANGE, from the trifoliate and sweet oranges. This is hardy north of the Orange Belt and is used chiefly for juice purposes. The LIMEQUAT is a blend of the lime and the kumquat, with small yellow highly acid fruit. It is hardier than the sweet orange.

Uses of Citrus Fruits

These have already been noted in part. Oranges are almost wholly used fresh, as breakfast or dessert fruit; an increasing use is in making orangeade and other acid drinks. Grapefruit are used fresh, canned, and in juice form. Lemons and limes are employed in lemonade, limeade, and other beverages.

About the middle of the eighteenth century, long before the discovery of vitamins, an English army surgeon named Lind discovered that the use of citrus fruit would prevent scurvy, a disease common among seamen on the restricted diets then necessary on long voyages. From that time on, sea captains carried bottled lime-juice to supplement scanty fare of ship-biscuits and salted meat. Vitamin research has rather recently indicated that juices of oranges and lemons are about four times richer than lime-juice in the antiscorbutic principal, Vitamin C. To-day the orange is the most important antiscorbutic food; the juice is employed, especially, to compensate for vitamin deficiency in infant diets based on pasteurized or canned milk.

The high glucose content of orange juice also renders it useful in special diets for certain types of invalids.

CITRUS BY-PRODUCTS

Careful means of culture and handling have greatly reduced the proportion of cull citrus fruit, yet there are considerable quantities of injured, deformed, and undersized oranges and lemons which in former years have been wasted. In Italy and Sicily, citrus oils are made from the peels (Fig. 321) and calcium citrate from the citric acid of the pulp. Of this acid the orange contains about 1 per cent and the lemon about 8 per cent. The oils, chiefly those of orange and lemon, are used in flavoring extracts and the calcium citrate in the re-making of citric acid, which in its turn is largely employed in beverage manufacture and for various technical purposes. Foreign processes have utilized both cheap material and cheap labor, and until recent years the United States has

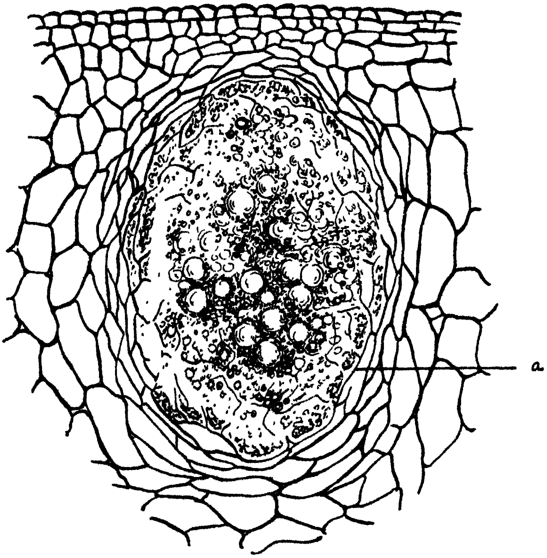

FIG. 321. — An Oil Gland in the Peel of a Citrus Fruit; *a*, secreting cells. Citrus oils are expressed or extracted from such glands in the rind of oranges, lemons, etc. (H. McCarthy.)

TABLE XVII

Citrus Fruit: Production in Thousands of Boxes by States and Kinds for Years Stated [1]

YEAR	ORANGES								GRAPEFRUIT					LEMONS	LIMES
	7 States	*California*	*Florida* [2]	*Texas*	*Arizona*	*Alabama* [3]	*Louisiana*	*Mississippi*	*4 States*	*California*	*Florida* [2]	*Texas*	*Arizona*	*California*	*Florida*
1899 [4]	6,167	5,882	273	.....	11	(5)	1	....	31	18	12	....	1	874	....
1909 [4]	19,530	14,440	4,888	11	33	1	152	5	1,186	123	1,062	(5)	1	2,756	11
1919	22,842	15,265	7,400	9	80	20	37	31	6,095	263	5,800	3	29	3,499	28
1920	30,005	21,296	8,500	......	60	82	42	25	5,738	304	5,400	....	34	4,955	....
1921	20,582	12,640	7,700	.....	80	82	50	30	6,795	360	6,400	....	35	4,050	....
1922	30,671	20,106	10,200	4	81	175	60	45	8,073	394	7,600	35	44	3,400	....
1923	37,484	24,137	12,900	6	86	225	75	55	8,893	363	8,400	65	65	6,732	....
1924	29,847	18,100	11,600	12	60	(5)	75	0	9,265	387	8,600	211	67	5,125	36
1925	33,623	24,200	9,100	10	86	100	100	27	8,190	600	7,300	200	90	7,316	30
1926	39,229	28,167	10,700	20	75	75	150	42	8,865	650	7,800	340	75	7,712	12
1927	31,644	23,000	8,200	30	54	110	200	50	8,586	720	7,200	490	176	6,000	0
1928	54,160	38,705	15,000	68	99	38	220	30	12,455	972	10,500	772	211	7,900	6
1929	34,034	24,400	8,800	261	137	212	187	37	11,095	1,000	8,200	1,530	365	5,900	8
1930	54,694	35,105	19,000	250	139	3	195	2	18,825	1,290	16,000	1,135	400	7,950	8
1931	49,734	34,900	13,800	520	145	70	245	54	15,147	2,017	10,200	2,480	450	7,800	9
1932 [6]	48,788	33,400	14,300	500	147	120	241	80	13,221	2,200	9,200	1,350	471	7,000	10

From United States Department of Agriculture *Yearbook*, 1933. Bureau of Agriculture Economics. Estimates of the Crop Reporting Board. Estimates of production for 1929 and 1930 revised on basis of 1930 Census. Earlier years not so revised.

[1] The figures in this table of production include fruit consumed on farms, sold locally, and used for manufacturing purposes, as well as that shipped. The figures do not include fruit which ripened on the trees, but which was destroyed by freezing or storms prior to picking. For California the figures relate to the crop produced from the bloom of the year shown, fruiting through the winter and through the spring and summer of the following year, being picked from Nov. 1 of the year shown to Oct. 31 of the following year. Fruit not picked until after the latter date is included with the crop of the following year. For all States except California the estimates include all fruit picked after about Sept. 1 of the year shown. The estimates for oranges include tangerines.

[2] From prospects on Dec. 1, commercial shipments of Florida citrus fruits from the 1932 crop were estimated at 11,800,000 boxes of oranges, and 6,700,000 boxes of grapefruit, compared with 11,200,000 boxes of oranges and 7,700,000 boxes of grapefruit shipped from the 1931 crop.

[3] For years 1919–1932, equivalent in standard boxes, each equal to about 2 of the "half straps" commonly used.

[4] Census. Size of boxes not specified.

[5] 500 boxes or less.

[6] As estimated from prospects on Dec. 1.

not been able effectually to compete. Research, largely under the United States Department of Agriculture, has developed means by which in a recent year one of two by-product plants in California utilized 40,000 tons of cull lemons, producing therefrom 2,000,000 pounds of citric acid, 65,000 pounds of lemon oil, and 30,000 pounds of pectin—the whole valued at $750,000. Another company produced $100,000 worth of orange oil from 10,000 pounds of surplus oranges.

The Citrus Crop of the United States

Orange, grapefruit, and lemons provide practically the whole commercial citrus crop of the United States. Amounts and locations of production for a series of years are shown in Table XVII.

World Production of Citrus Fruits

The United States has for some years been the largest national producer of oranges and lemons, which are the principal citrus fruit of world trade. Spain grows about as many oranges as California and Italy somewhat less than Florida. Japan ranks next to Spain, and Palestine and Australia each produce about 2,000,000 boxes annually. Only about 8 per cent of American oranges are exported; of these Canada takes 80 per cent. Mediterranean Europe supplies northern Europe with oranges and lemons; of the latter fruit Italy produces rather more than the United States. Twenty per cent of the lemons used in the American market are from Italy. Outside the United States, grapefruit are grown chiefly in the West Indies. Limes occur throughout the tropics; our supplies come from Jamaica, other West Indies, and Mexico.

3. GRAPES

All grapes are species and hybrids of *Vitis*, the principal genus of the Vitaceæ. Nearly all those in cultivation are derived from *Vitis vinifera*, the Wine or Raisin Grape of Europe; from *V. Labrusca*, the Fox Grape of the Eastern United States; or from hybrids of the two. *Vitis rotundifolia*, the Southern Fox or Muscadine Grape, is a favorite from Delaware southward, but rarely cultivated elsewhere. Some others of about two dozen species of this genus have been occasionally cultivated or used for hybridizing.

The Vine and Its Fruit

The stem of the grapevine is of rapid growth and coarse woody texture. Its length-growth is extremely rapid; the diameter attained by the trunk is partially a species characteristic and in part a result of training. All grapes in cultivation are drastically pruned; American varieties are generally trained in slender forms; occasionally in the forest their trunks may reach considerable diameter (Fig. 322). The European grape is more stocky,

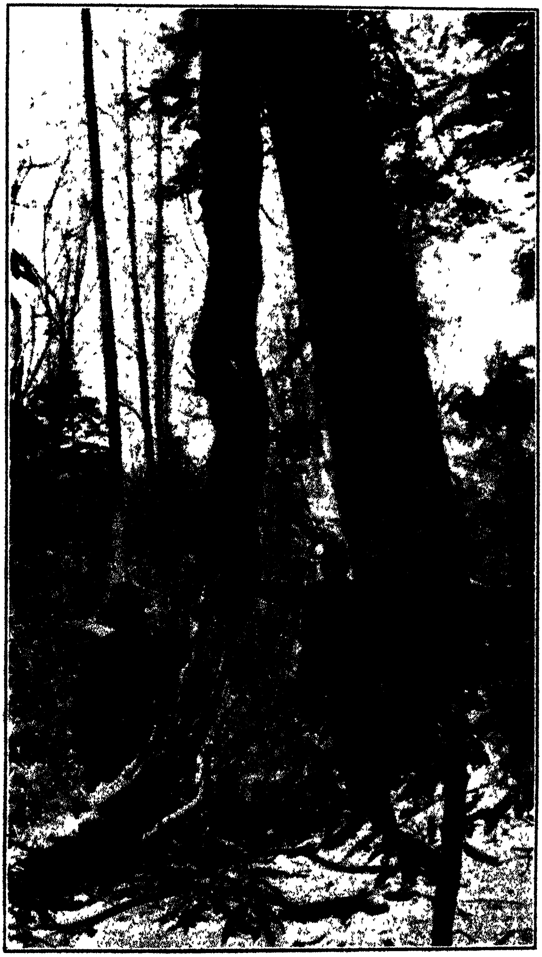

FIG. 322. — A Huge Wild Grapevine in Great Smoky Mountains National Park. This was 60½ inches in circumference. (Courtesy of National Park Service.)

particularly as trained in California, where grape-growers who found themselves in recent years overplanted were able at least to realize a trifle from the use of vines as fuel.

Nodes, in most cases solid, form prominent swellings on the slender young stems. Tendrils, which are considered modified branches, are borne opposite the leaves, as are the flower-clusters on the canes of the current season's growth. Leaves are ample, palmate, more or less orbicular in general outline, and in most varieties somewhat lobed.

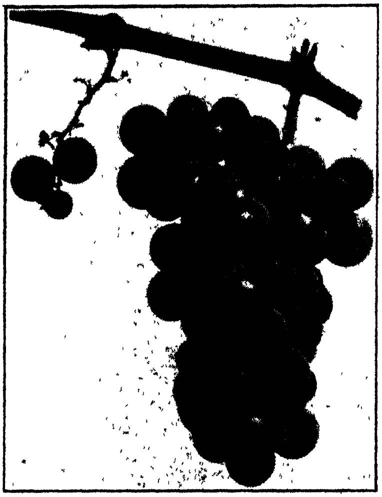

FIG. 323. — Self-Sterility in Grapes. The variety shown, Eclipse, is a hybrid between *Vitis Labrusca* and *V. vinifera*; it is highly self-sterile. The flower-cluster on the left contained fifty-eight flowers; it was left open under conditions in which self-pollination would be likely to take place. The cluster on the right, containing eighty-four flowers, was hand-pollinated from another variety and bagged for protection until fertilization had taken place. The fruit-clusters weigh 4 and 136 grams, respectively. (Courtesy of New York Agricultural Experiment Station.)

The small greenish flowers of the grape occur in large compound panicles or thyrses. The blooms are polygamo-dioecious; in wild grapes some vines bear perfect flowers which are self-sterile, while others are staminate. Self-sterility is also observable among cultivated grapes (Fig. 323); but merely staminate types, not being needed for pollination, are not planted. The calyx is rimlike and rudimentary; the petals are separate at base but united at the top. As the flower opens the petals break away at the base and fall, still attached at the tips. Conspicuous nectar-glands occur at the base of the pear-shaped pistil.

The fruit of the grape is a spherical or elongated two-celled berry, with one or more seeds in each cell. Grapes differ not only in appearance and flavor, but in quantity of sugar, acids, and solids.

THE OLD-WORLD GRAPE

Vitis vinifera (Fig. 324) has been cultivated in Europe and the Mediterranean Basin since prehistoric time. It was among the earliest European fruit-bearing plants to be introduced to the New World, being brought over by Lord Baltimore in 1616. This and repeated subsequent attempts to cultivate the wine grape outdoors on the Eastern seaboard failed. It proved non-hardy in the North, and in the South it fell victim to disease and to the *Phylloxera* or root-louse. This insect, incidentally, later gained entrance to Europe; disaster to the vine industry was avoided only by grafting vinifera grapes upon the resistant root-system of the American *V. Labrusca.*

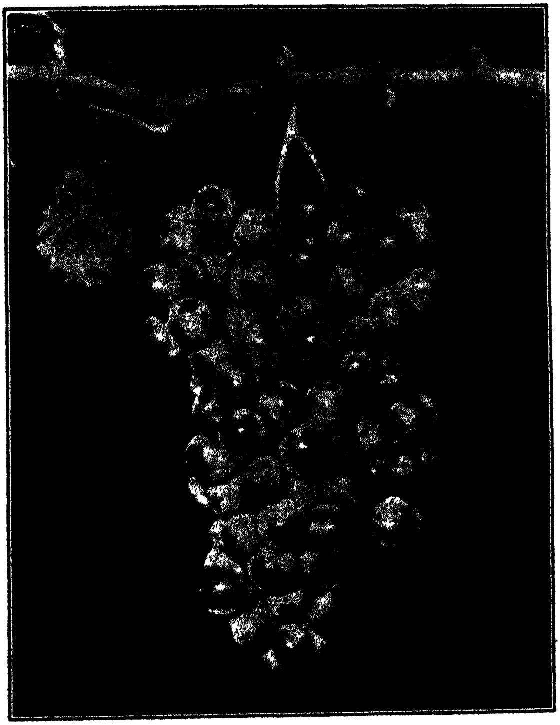

FIG. 324. — The European Grape (*Vitis vinifera*); a variety grown in California. (Courtesy of Sunland Sales Cooperative Association.)

THE GRAPE IN CALIFORNIA

The principal development of Old World grapes in the United States has been in California, where it is one of the most important of many large fruit-growing interests. Here the vine is trained to a short, stout stock, or stump, three or four feet in height, from which a few whiplike fruiting branches are allowed to grow each year. Some kinds of slender habit may be trellised, like Eastern grapes.

The berry of the Old World grape is usually of elongated form. The skin does not slip from the solid, sugary pulp. The flavor is sweet, lacking the raciness of Labrusca grapes, which are somewhat used to hybridize with the less sprightly European types. Californian grapes have been grown for table, wine, and raisin purposes. Their keeping quality excels that of Labrusca grapes; packed in sawdust, they ship readily across the continent and may be held some months in cold storage. Prohibition enactment failed to bring immediate disaster to the wine-grape industry; in fact, from 1921 to 1928 the production of grapes in the United States increased about 200,000,000 pounds per year. From 1926, a decided overproduction of California grapes became evident; 142,000 tons were not harvested in 1927 and 148,000 tons went to waste in 1928. The year 1931 witnessed the establishment of a grape-concentrate industry concerning the legality of which some doubt arose in prohibition enforcement circles.

Raisin production.—Raisins are made only from vinifera grapes of high sugar content and meatiness. Production in California is largely limited to three varieties: Sultanina (Thompson Seedless) (Fig. 325) and Sultana, both of which lack seeds; and Muscat, a large grape from which seeded raisins are made. These are grown under irrigation in the region centering around Fresno. Here the grapes ripen during hot, dry weather. Commercial drying is a more technical and highly systematized process than a brief account of it may indicate. The grapes are gathered on small trays and dried in the sun between the vine-rows. Muscats dry in about two weeks of suitable weather. Rain-wet and darkened raisins are partially bleached with sulphur fumes. Dipped raisins are made by plunging the ripe fruit in a lye-dip for a moment; they are then rinsed, sulphured for three hours, and dried. Stemming, seeding, and packing is done by machinery. Before drying, seedless raisins are oil-dipped in a mixture of weak soda-solution and olive oil. This tends to prevent sticking and imparts a semi-gloss.

In the northern portion of the Raisin Belt artificial heat may be used in drying.

From three to five pounds of grapes yield one pound of raisins.

THE FOX GRAPE

Vitis Labrusca is native to the eastern United States, where a great variety of kinds have been developed by selection and hybridization. Labrusca types are slender, tough vines, usually grown on wire trellises. Berries are spherical, with sweet but racily acid, watery pulp which parts readily from the skin upon pressure. Colors vary; most common is blue, with decided bloom.

FIG. 325. — Thompson Seedless Grapes, the Principal Source of Seedless Raisins. (Courtesy of Sunland Sales Coöperative Association.)

Some varieties are red and a few white. Concord (Fig. 326) the principal commercial kind, was introduced from Concord, Mass., about 1853 by Ephraim Bull. The Concord grape has been said to have an infusion of vinifera "blood," and cited as an example of early success in hybridizing. Most students of the grape, however, appear to consider the Concord pure Labrusca. Catawba, a later red variety, and the popular white Niagara are probably of hybrid origin.

Labrusca grapes ship and keep poorly; they are chiefly used for fresh eating and for the common bottled unfermented grape juice, which is chiefly derived from the Concord variety. Grape preserves and jellies are popular, particularly in domestic manufacture.

Fox grapes are grown throughout their natural range. The center of commercial cultivation is in western and central New York (Fig. 327). In California the climate is rather hot and dry for them; there they are chiefly valued for hybridizing with vinifera varieties and for grafting stock where the phylloxera has been introduced.

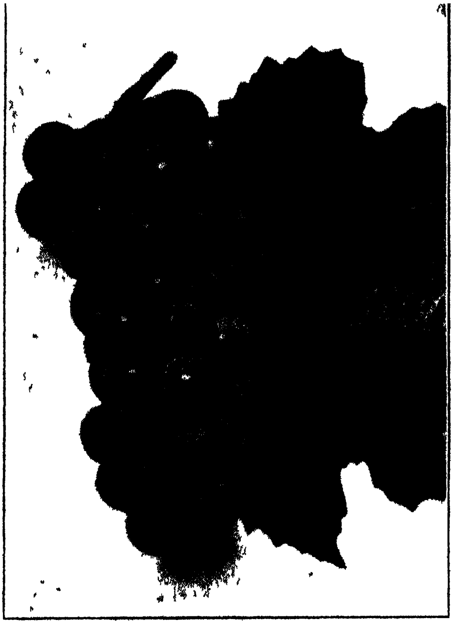

Fig. 326. — A Bunch of Concord Grapes. (Photo from New York Agricultural Experiment Station.)

THE MUSCADINE GRAPE

Vitis rotundifolia (Fig. 328) is a vigorous vine with very large tough-skinned sweet grapes borne in small clusters. The most common variety is the Scuppernong. Muscadine grapes are grown

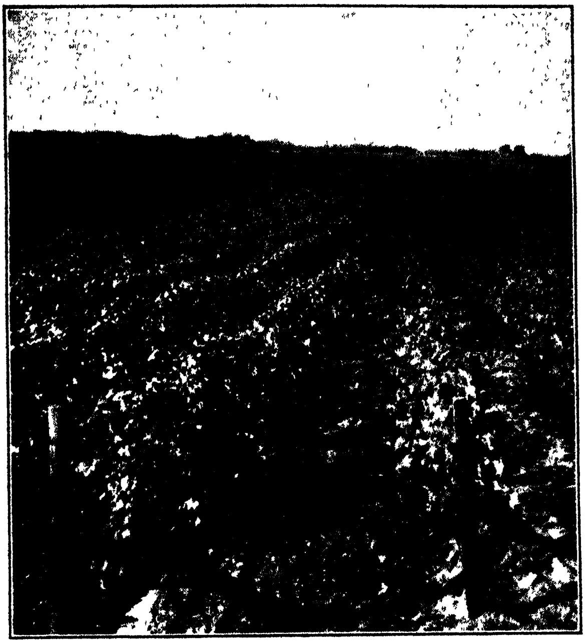

FIG. 327. — Concord Grapes, Grown on the Trellis System, in western New York. (Photo from New York Agricultural Experiment Station.)

FIG. 328. — Muscadine Grapes (*Vitis rotundifolia*) in North Carolina. A common method of training this grape. (Courtesy Bureau of Plant Industry.)

in the South for local consumption and wine-making. Despite their tough skin, they do not ship well.

World Production of Grapes

Grape culture is a most important industry throughout continental Europe from Germany southward, and particularly in the Mediterranean Basin. Table and raisin grape-growing is unimportant in comparison with the wine-grape industry. Spain's exports of table grapes, averaging about 95,000,000 pounds annually, are only 1 per cent of that country's total grape production. Outside southern Europe, Argentina, Chile, Australia, and South Africa are large grape-producing regions. Prior to 1923, the United States imported considerable quantities of table grapes from Spain, but a quarantine against the Mediterranean fruit fly now prohibits imports from that part of the world. Present-day grape imports are from Argentina and Chile, with some hothouse grapes from Belgium.

CHAPTER XIV

SPICES AND OTHER AROMATIC PRODUCTS

Spices are of very ancient history. Primitive peoples valued them as condiments and knew of their preservative value in lands where refrigeration was non-existent. Ancient Egyptians used them to perfume the person and to embalm the dead. Throughout the Middle Ages, when bathtubs were not, spices made social intercourse more tolerable.

Spices are of varied kinds, from many plant parts, and from several climes. In general, powerful aromatics are found in storage regions—in barks, fruits, underground stems. Many families are represented; the Lauraceæ, the Myrtaceæ, the Umbelliferæ, and the Zingiberaceæ perhaps lead. Not a plant-harboring region lacks aromatics, but, as though their pungency were condensed from the very sun overhead, the most powerful and the most commonly used come from the Torrid Zone. Always the spice trade has centered in the Orient; thence come pepper, cinnamon, and ginger; there are used other aromatics which make no appeal to the Occidental taste. As if lured by actual spicy breezes, Portuguese and Dutch navigators crept warily round the bulk of Africa; one sailor, bolder than all the rest, sought in the West the spices of the East, and found a New World. Battling for spices, Portuguese, Dutch, French, and English left a trail of blood in the Indies and in India. Spices to-day are a minor issue there, but the end of the trail of blood is not yet.

Active Principles of Spices

Of active principles represented in spices, many belong to that rather vague class of volatile or essential oils; others are closely related thereto. Alkaloids, better known from the powerful poisons of that class, have spice-representatives.

The term VOLATILE OIL embraces such a variety of substances that it scarcely can be defined. Substances so classed are generally labile liquids; some are semisolid and others contain ingredients solid at ordinary temperatures. Volatile oils are practically insoluble in water; while their boiling points are usually high, they volatilize readily with steam—a characteristic which is utilized in their commercial distillation from plants in which they occur. Some, such as oil of wintergreen (methyl salicylate) are practically pure chemical individuals; others are very complex mixtures which can be separated—fractionated—by differences in the boiling or melting-points of the constituents. Volatile oils are usually responsible for characteristic aromas of plants in which they occur. They are by no means confined to spice-plants; few, if any, higher plants wholly lack them. Aromatic constituents lend flavor to pot-herbs and commercial value to mints and other plants whose main use is distillation for oil. Oils of flowers—and their imitations—parade as perfumes.

Volatile oil content of plant parts is usually small; generally less than 5 per cent of the weight of the dried product, and frequently much less. Cloves, unusual in this respect, yield 15–18 per cent.

Physiological Significances of Aromatic Substances

While used mainly in foods, spices themselves can hardly be classed as foods in any proper sense. Some stimulate the appetite. Some are classed as medicines, although in most pharmaceutical preparations in which they occur they function mainly as flavors and preservatives. They retard bacterial action and therefore delay decomposition. In the small quantities ordinarily used they impart agreeable flavors and disguise disagreeable ones—a desirable effect in disguising unpleasant medicinal mixtures but less so when hiding incipient putrefaction in sausages or the flavor of mold in tomato products. Preservative use of spices has fallen with the rise of refrigeration, although it will continue till the human taste for pickles fails.

In concentration, volatile oils are irritant poisons.

The value of aromatics to the plants which produce them is debatable. They seem to be by-products of plant metabolism rather than food or constructive material. In high concentration they may be repellent to plant-devouring animals and insects. Odors of flowers are said to attract insects useful in pollination.

Commercial Forms of Spices

Spices are generally employed in powdered form, but they are almost invariably imported in the crude state. One apparent reason for this is a tariff differential favoring the crude products by imposing on the powder a duty more than sufficient to balance the American costs of grinding. This is in line with a general American tariff policy which favors domestic manufacture by admitting crude products free or at low duty while processed material is taxed or taxed higher. From the consumer's point of view, there is another reason for preferring American-ground drugs and spices. Powdered products are very easily admixed with adulterations most difficult to detect, and moldy or wormy materials lose the telltale appearance of damage. Oriental laws against sophistication are lax or lacking, and the Oriental conscience most untrustworthy. When drugs and spices are ground in the United States, the process can be adequately supervised and the raw materials and finished products inspected by federal and State authority. The passage of the famous Food and Drugs Act of 1906, commonly known as the Pure Food Law, was due in no small degree to the necessity of correcting conditions in the spice industry.

A few products, such as paprika and red pepper and white mustard, are exceptions to the general rule in that they are mostly imported in powdered form.

1. The Principal Spices

There is no very distinct dividing line between spices, flavoring products, pot-herbs, oil-plants, and perfumes. The members of all these ill-defined classes are numerous. Aroma-valuation varies in different parts of the world. Asafetida, a condiment of India, and the garlic of the Latin, are not welcomed in our society. Europeans find little to admire in a spearmint-flavored breath. Detailed discussion can be accorded only a few spices and near-spices particularly valued in American use.

Black Pepper and White Pepper

The term **pepper** has been applied to a number of very powerful and "hot" aromatics. Properly it belongs to the small drupe-like fruit—the so-called berry—of *Piper nigrum* of the Piperaceæ, whose principal preparation is black pepper. Less justifiable, though thoroughly established, is its application to the pungent, succulent fruit of *Capsicum*—Red Pepper—of the Solanaceæ.

The biting berries of pepper were among the first spices of history. Theophrastus, Dioscorides, and Pliny mention pepper. As European commerce developed, pepper was the chief article of trade between India and Europe. Tribute of gold, silver, and pepper was exacted by Alaric the Goth from beleaguered Rome. In the Middle Ages it was most valued of spices; wealth of pepper helped to build Genoa and Venice. Before the travels of the Portuguese round the Cape, Englishmen paid tribute and rents in pepper; when at last hardy mariners had looped the long journey to Malacca, the pepper trade passed from Venice to Portugal, and later from Portugal to Holland. At present, this native spice of the Malabar Coast of India is widely cultivated there and in Ceylon, Cambodia, Malaya, Sumatra and the South Sea Islands, and to a limited extent in Africa.

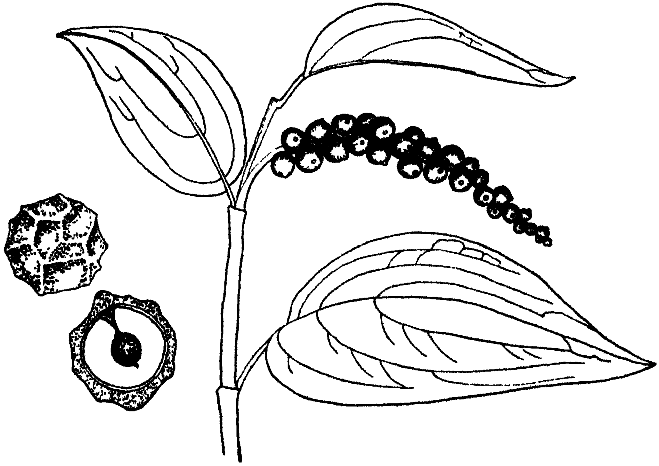

FIG. 329. — Fruiting Branch of *Piper nigrum*. Dried "peppercorns," outside view and in section, at left. (E. Coffman.)

THE PEPPER PLANT

Piper nigrum is a woody climber with a stem about half an inch in diameter. It attains a considerable length in the wild; cultivated vines are trained and trimmed for ease in picking. Adventitious roots are produced from the nodes. Leaves are alternate ovate or lanceolate, coriaceous and evergreen. Very small and much reduced flowers grow in catkinlike spikes, which may be pistillate, staminate, or perfect. Bearing spikes (Fig. 329) reach a length of about four inches, and may have fifty fruits, each about one-fifth inch in diameter and bright red at maturity. Within the juicy red pericarp, which becomes wrinkled and blackened on drying, is a single globular seed. This consists mainly of a grayish white, starchy perisperm, a small endosperm, and a scarcely developed embryo.

Culture and harvest.—As a profitable crop, pepper is confined to tropical regions of heavy rainfall. The plant is generally grown from cuttings, and trained on stakes or trellises or—as shade is desirable in most regions—on living trees. Species with rough bark make the best supports. Pepper vines are severely pruned and trained to bushy form. They are first allowed to fruit at two and a half to five years and continue bearing twelve to twenty-five years. They flower rather irregularly and may be so handled

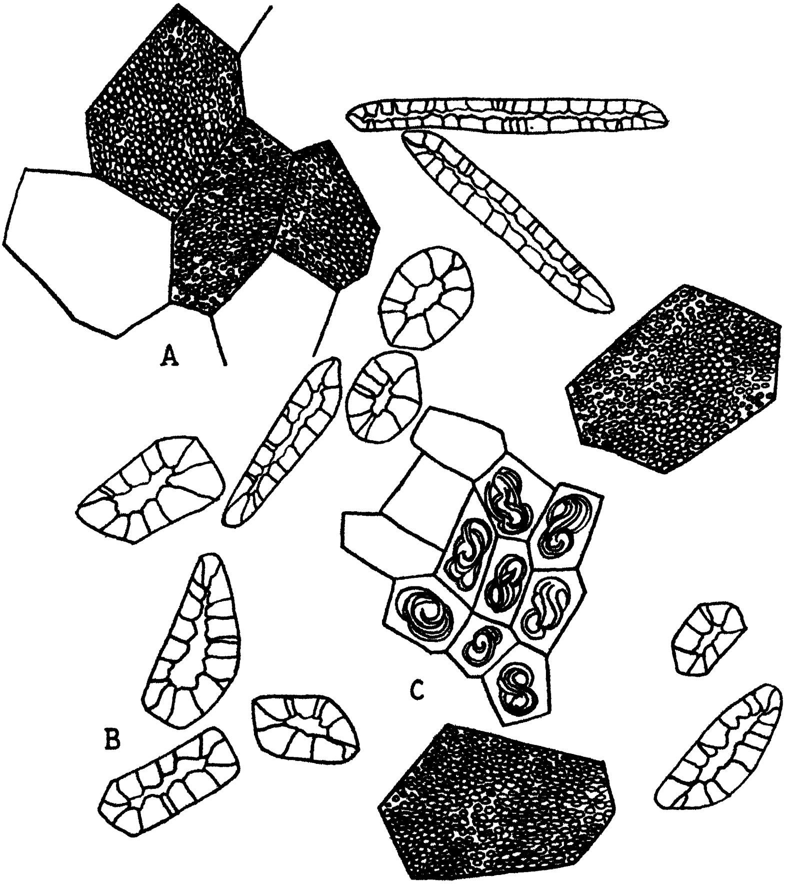

FIG. 330. — Ground Black Pepper. *A*, parenchyma cells, packed with fine granular starch; *B*, stone-cells; *C*, epidermal tissues. (E. Coffman.)

as to fruit throughout the year or to furnish annual or semi-annual crops.

Ordinary black pepper is gathered when only a few of the fruits of a spike have turned ripe and red. It is sun-dried; before drying it may be plunged in boiling water. Dried pepper is rubbed by hand to separate the stems, which are winnowed out. In some localities pepper is smoke-cured.

White pepper consists of the seed only. Two methods are used to remove the pericarp. In the older usage, the berries are allowed to ripen; after collection they are fermented in water until the pulp softens and can be trodden off and separated by washing. In Europe and America the spice is made in a less unappetizing way by milling black pepper in machines which rub off the dried pericarp. The blackish pulverulent portions removed are known as "pepper shells"; they have been used as adulterants of ground black pepper. Because of the difficulty of detecting this sophistication, importation of pepper shells to America is prohibited.

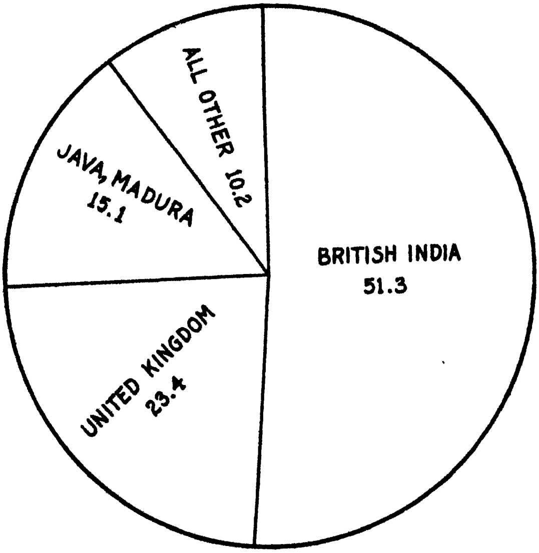

FIG. 331. — Sources of American Imports of Unground Black Pepper, for a Selected Year, the Total Being 23,907,000 Pounds. (From statistics by United States Tariff Commission.)

White pepper is less pungent than the black spice; because of its color it is less conspicuous and "dirty" in cooking; to some tastes the flavor is finer.

CONSTITUENTS AND USES OF PEPPER

Pepper owes its pungency to several substances. Of these the largest in quantity is the alkaloid piperine, ranging from 4.5 to 8 per cent. Piperidine—which is a derivative of piperine—a complex volatile oil, and a pungent resin, also occur.

Pepper is one of the most widely used of spices; amounts brought into this country (Table XVIII) are largest of American spice imports. Fig. 331 shows sources of American imports of black pepper. The distribution indicates considerable trans-shipment. The use of pepper in medicine, once considerable, is nearly obsolete.

Red Pepper

The genus *Capsicum,* of the Solanaceæ, includes about fifty species of annual or perennial pungent-fruited herbs, vines, and shrubs, of which the tropical American *C. frutescens*—Chili, Cayenne Pepper, or Red Pepper—yields several varieties to cultivation. Some of these are so diverse as to be ranked as species by some authors.

The first European observation of *Capsicum* is by Chanca, a physician of Columbus' second voyage, who referred to it by the Mexican name of *agí,* by which it is still known in Spanish. By fifty years later, at most, the plant was well known in India; it was distributed widely in the tropics before 1600. In many localities it has become naturalized, the seeds being distributed by birds.

Capsicum frutescens (Fig. 332) is a perennial woody plant capable of becoming a considerable shrub, but generally grown as a herbaceous, long-season annual. The leaves are ovate or elliptic-lanceolate; the flowers are usually white, with rotate slightly five-lobed corolla. The fruit, for which the plant is grown, is a podlike indehiscent berry, varying greatly in size and shape as well as in pungency in different varieties. Seeds are numerous and flattened.

Best known in American cultivation, and sometimes segregated as a species, is *C. annuum,* the Bell or Sweet Pepper, a mild, large-fruited form commonly grown for use when fresh. Like other Capsicums, it is American in origin, but has been grown elsewhere so long that distinct strains have been developed. Paprika, or Hungarian Paprika, is a spice derived by grinding the dried fruits of a variety developed in Hungary. Pimenton, Pimiento, or Spanish Paprika, is a variety of Spain, thence imported in canned form. It is also grown in the United States, especially in California and Georgia. Preserved pimientos are used in making pimiento cheese.

Chillies, Capsicum, Cayenne, or Red Pepper are a number of terms used more or less interchangeably for many varieties of shrubby, highly pungent peppers, widely cultivated as field crops throughout the tropics and generally known by their geographical origins. The fruits are usually elongate-conical, differing greatly in size, shape, and pungency. They are dried in sun or sometimes by artificial heat. Hottest and most valued are African chillies or cayenne, from Mombasa, Zanzibar, British East Africa, and Sierra Leone. Only African peppers are specified in the United States Pharmacopœia for the limited medicinal use which capsicum still maintains as an irritant and blister. The chief red pepper of world trade is Madras or Bombay chillies from British India, although of recent years the largest quantity of American chillies imports has come from Japan. Of late years the red pepper crop of Louisiana has attained some importance.

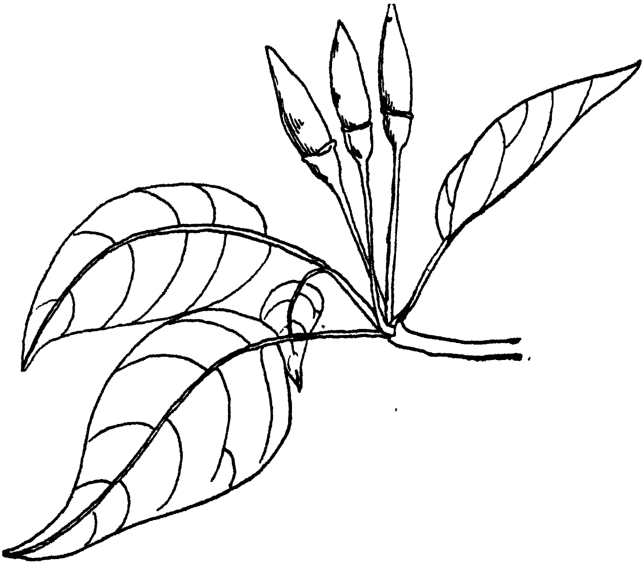

FIG. 332. — Fruiting Branch of *Capsicum frutescens*. (E. Coffman.)

Constituents and Uses.—Red peppers owe their pungency to complex crystallizable principles, capsaicin and capsacutin. They also contain an alkaloid and a volatile oil. So pungent is capsacutin that 1 part in 11,000,000 parts of water can be distinctly tasted. African chillies are perceptible in the ratio of 1 part in 70,000 of sweetened water, while those from Japan and India can be tasted in dilutions of 1 : 50,000 and 1 : 40,000 respectively.

Red peppers are an important spice and food constituent in most tropical countries and in the Latin Americas and southern Europe. With us they are employed in Tabasco and various other "hot" sauces, in highly flavored dishes such as tamales and chili con carne, and in pickled vegetables and meats. In regions of production large quantities are used without drying.

Nutmeg and Mace

These products, respectively, are the seed-kernel and the arillus or arillode of the seed of *Myristica fragrans,* a small tropical evergreen tree of the Myristicaceæ, native to the Moluccas, or Spice Islands.

Nutmeg and mace were famous spices of early trade. They were introduced to Europe by Arab traders about 1195. A century later two pounds of mace in England were worth as much as a cow or six sheep. The Portuguese, taking possession of the Spice Islands in 1512, monopolized the trade until they were driven out by the Dutch, who controlled the spice trade for many years thereafter. Early attempts were made to limit nutmeg production to Amboyna, one of the larger Moluccas, and to the Banda Islands, another group which is still dominant in the nutmeg trade. Fruit pigeons, however, swallowed the large indigestible seeds and voided them on neighboring islands. Eventually the culture of nutmegs spread to Penang in Malaya and elsewhere in the East Indies and later to Grenada and Trinidad, British possessions in the New World. Rubber has in recent years tended to crowd the nutmeg out of Malaya.

THE NUTMEG TREE AND ITS PRODUCTS

Myristica fragrans (Fig. 333) is a bushy evergreen reaching forty feet in height, though generally headed lower in cultivation. Leaves are alternate, lanceolate and acuminate, about four inches long and two and a half inches wide, glabrous and deep green when well nourished and yellowish under unfavorable conditions. The trees are usually dioecious; though sometimes bisexual; occasionally staminate trees "change over," becoming by degrees pistillate. Flowers are small, yellowish, apetalous with three-lobed calyx. The fruit has been described as one of the most beautiful in nature; it is pyriform or globular, one and one half and two inches long, pale orange, with a groove at the side.

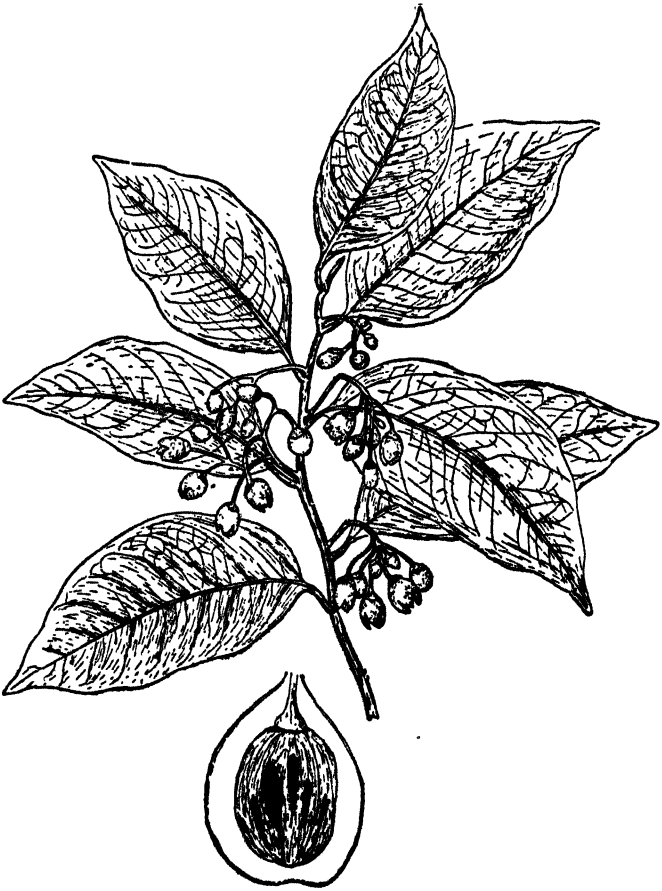

Fig. 333. — Nutmeg (*Myristica fragrans*). The fruit, in section, shows mace covering the nutmeg. (From Sayre, *Organic Materia Medica and Pharmacognosy*, P. Blakiston's Son & Co., Inc.)

The fleshy pericarp splits along the groove at maturity, allowing the seed to fall. This is enwrapped by a basally attached leathery scarlet arillode, which is cut into coarse fingerlike projections surrounding the seed. This arillode, removed and dried, becomes mace. With the arillode is the seed-coat or testa; this encloses the kernel, the familiar nutmeg, which is about an inch in length. The bulk of the nutmeg is of dark brown perisperm and lighter endosperm, intricately interfolded and enwrapping an inconspicuous embryo.

Culture and harvest.—The principal cultivation of the nutmeg is on small islands with much rainfall and no prolonged dry season. Seeds quickly lose their viability, and are generally planted directly after gathering. As only a few staminate plants are required for pollination, seedlings may be allowed to grow in nursery rows till flowering indicates their sex; as this may require several years, the seedlings are sometimes budded from known pistillate stock. Staminate branches are occasionally grafted into pistillate trees. In some localities the young trees are shaded; in others, as in Penang, they are grown in the open on terraced hillsides.

Trees about fifteen years from setting bear maximum crops of 2,000 to 5,000 nutmegs per year. Early fruiting—before the ninth year—is discouraged as being exhaustive to the tree. The nutmeg fruits irregularly throughout the year; there usually are two, and sometimes three, main crops. Hand-picking of the fruit is preferable, but it is often allowed to crack upon the tree, when the seeds fall and are picked up. The mace is peeled off, flattened by hand, underfoot, or between boards, and sun-dried till its brilliant scarlet becomes orange-brown. The ratio of yield is about 1 pound of mace to 10 pounds of nutmegs.

The kernels are allowed to dry in their seed-coats, in sun or by artificial heat, after which the testa is carefully cracked off. While aromatic products are generally repellent to insects, shelled nutmegs are very likely to become infested with beetle-larvæ. The housewife's preference for whole rather than powdered nutmeg has therefore some justification. To repel insects, nutmegs are sometimes rubbed with powdered lime or dipped in lime and water.

Constituents and uses.—Nutmegs contain 25-40 per cent of a fixed oil—nutmeg butter—which is sometimes extracted. Content of the aromatic volatile oil ranges from 8 to 15 per cent. Both oils may be used in soap-making. Mace contains 20 to 25 per cent of an aromatic balsamic substance and 4 to 7 per cent of a fixed oil resembling that of nutmegs.

Nutmegs and mace are used mainly as mild spice in pastries and desserts. Mace is more delicately flavored, and higher in price. Whole nutmeg fruits, and the husks or pericarps, are employed in the Orient in jellies and preserves.

OTHER "NUTMEGS"

Many wild *Myristica* species are known; their inferior seeds are used by Oriental peoples and sometimes occur mixed with true nutmegs. Factitious nutmegs have been made by molding exhausted nutmeg powder into kernel-like forms. The "Nutmeg State" draws its popular name from a tradition that Connecticut Yankee peddlers of a century past used to vend "nutmegs" whittled from basswood and artificially stained. Despite the undoubted skill of the Yankee with the jack-knife, it is quite possible that the story rather than the wooden nutmeg is Yankee invention.

The Cinnamons

HISTORY

The spice cinnamons are derived from barks of various species of *Cinnamomum* of the Lauraceæ, a large family of aromatic trees and shrubs, mostly tropical. *Cinnamomum* is indigenous to Asia and adjacent islands; one species, *C. Camphora,* source of camphor, will be discussed on a later page. The different species of the spice trade are not too clearly defined; their past history, particularly, is blended. Cinnamon of some sort was an early article of trade between China and Arabia, and both cinnamon and cassia are mentioned in Old and New Testaments. Western Europe's direct trade in cinnamon began in 1505, when Portuguese navigators discovered Ceylon, which island they seized in 1636 because of that spice. At that time the bark of wild trees only was used, and of it the Portuguese levied tribute from the native rulers. The caste of cinnamon collectors —Chulias—was cruelly oppressed, first by the Portuguese and later by the Dutch, who expelled the Portuguese from Ceylon in 1656. While Indian and white man strove for the mastery of a newly discovered continent in the West, in the Far East the greed for spices wrote one of the blackest chapters in the troubled history of European dealing with darker races. The Dutch brought cinnamon under cultivation in Ceylon about 1770. Cinnamon trade of the Dutch monopoly approximated 400,000 pounds per year; when oversupply threatened the price, the humid air of the Netherlands was perfumed with the burning spice for the sake of whose aroma Singhalese had been tortured and slain. In 1796 the English drove out the Dutch, and seized the cinnamon monopoly, which passed to the East India Company until 1833, when the monopoly was abolished. While Ceylon cinnamon is now scatteringly cultivated elsewhere in the Far East, it is still the most important spice crop of Ceylon; that island in 1927 furnished 96.6 per cent of American imports of cinnamon aside from cassia.

Cassia is probably indigenous to Cochin China but was long ago introduced to cultivation in southern China. It is probably one of the oldest, if not the oldest, of cultivated spices. It is mentioned in Chinese medical works of about 2700 B.C., but its botanical origin was not known to Europeans till 1882 A.D.

THE CINNAMON SPECIES

Three principal cinnamons enter the American market: CEYLON CINNAMON, from *Cinnamomum zeylanicum;* SAIGON CINNAMON, from *C. Loureirii;* and CASSIA CINNAMON or CASSIA, from *Cinnamomum Cassia.* Barks of other species are also known as cassia.

The trees in cultivation are small or medium-sized bushy-headed evergreens, with dark green, simple leaves of somewhat variable form; small yellowish or yellowish white flowers in compound panicles; and small blackish drupelike fruits enclosed at the base in the cuplike remains of the perianth. All parts of the trees are aromatic, but spice-products are chiefly from the inner bark of smaller shoots and branches. Outer grayish layers of older tree-parts soon become corky and lacking in aroma.

Ceylon cinnamon.—*Cinnamomum zeylanicum* is chiefly cultivated in the sandy lands of western Ceylon at rather low elevations. Trees grown in swampy soil are deficient in aroma. Propagation is usually from seed, although cuttings may be used. The trees are coppiced, or cut back to stimulate the growth of long, slender, whiplike shoots. The first cutting is made at four to six years. After this a second crop can be gathered in about two years, and several subsequent crops may be obtained. Harvest is between May and October, following rains. The thin bark is slit lengthwise with a copper knife, loosened, and allowed partially to dry on the stem, after which the corky periderm is carefully scraped off with a curved knife. The remaining quill-like cylinder of inner bark is paper-thin and pale yellow; it dries to a light brown. When fully dry Ceylon cinnamon is put up for market in compact canelike bundles about four feet long, formed by placing small quills concentrically within larger ones. These bundles are called pipes. The best cinnamon is said to come from the middle of the shoot. Trimmings, broken pieces, and coarse bark are called cinnamon chips.

Ceylon cinnamon is considered the most delicate of these spices in flavor, having a sweet aroma quite distinct from Saigon or Cassia cinnamon. The oil-yield is from 0.5 to 1 per cent. Its chief constituent is cinnamic aldehyde.

Cinnamon leaf oil is somewhat similar to clove oil and is sometimes used as a substitute for it.

Saigon cinnamon.—This is cultivated in Cochin China and exported from Saigon. The bark is rather coarse in appearance, usually retaining its periderm, and sometimes patched with lichens. It is pungently aromatic, yielding from 3 to 6 per cent of oil, and is the only cinnamon recognized for medicinal use by the United States Pharmacopœia. Import information indicates that very little Saigon cinnamon enters American trade.

Cassia.—This is the principal spice of the cinnamon group used in the United States. *Cinnamomum Cassia* (Fig. 334) is probably indigenous to Cochin China, but is grown most extensively and almost wholly in southeastern China. Other cassias from the Dutch East Indies are probably largely from other species.

Cinnamomum Cassia is cultivated on terraced hillsides, trained in low bushy much-branched forms, and cut at six years, when the principal branches are about an inch in diameter. The peeling season is from March through May. Bark is slit and peeled off in semi-cylinders about sixteen inches long. These are flattened and the periderm is removed with a small plane; upon drying the innermost bark next the cambium shrinks most; the pieces assume a quill-like shape and a rich brown color.

Cassia "buds," also used for spice, are the dried unripe fruits.

Cassia bark yields 0.93 to 1.64 per cent of oil, of which 80 per cent is cinnamic aldehyde. The oil of cinnamon or oil of cassia, one of the more important Oriental volatile oils, is made mainly by steam distilling twigs and leaves of the peeled shoots.

Inferior grades of cassia are obtained from wild trees of Annam, Indo-China, and the Dutch East Indies. Batavia Cassia is attributed to *Cinnamomum Burmanni;* it is somewhat mucilaginous in character.

Java and Madura are now considerable sources of cassia; 41.5 per cent of 1927 imports were from Dutch sources, while 50.6 per cent came from China and Hong Kong.

As a spice, cassia is considered inferior to the other cinnamons; this may be due in part to less careful methods of preparation and to the various sources from which the spice is derived.

USES OF CINNAMONS

The cinnamons are mainly used as spices of cakes and pastries; use in medicine is slight and mainly for flavoring value. Cinnamon aroma is often perceptible in incense and is blended in perfumes. Cinnamon oil flavors Christmas candy, "mints," and similar confections, and sometimes appears in toilet soaps.

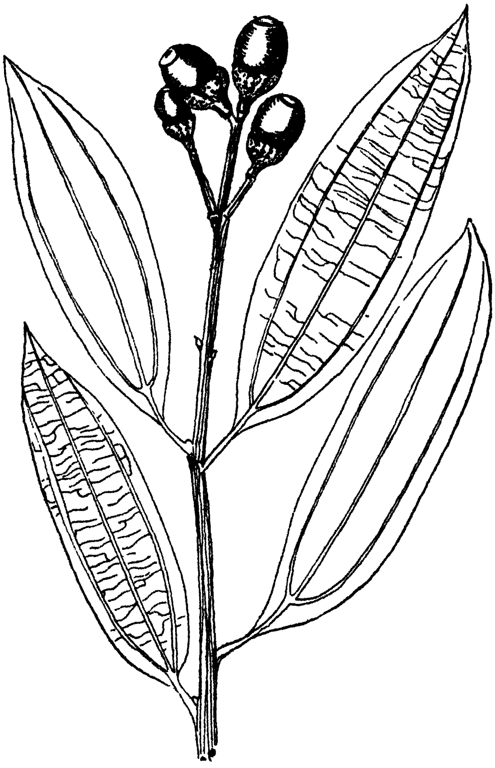

FIG. 334. — Fruiting Branch of *Cinnamomum Cassia*. (E. Coffman.)

Sassafras

An American relative of the cinnamons is *Sassafras variifolium*, a familiar aromatic tree of Appalachian and Mid-west woodlands. The Indians knew its spicy root-bark; colonists employed it as a domestic remedy, and later generations have used it in root-beer and patent medicines. Its oil was once extensively distilled in the Southern mountains for use in cough drops, soaps, and perfumes; it has been largely replaced by the cheaper oil of camphor.

The Mustards

Plants of the Cruciferæ or Mustard Family are usually distinguishable by peculiar odors derived from various compounds of sulphur. The seeds of *Sinapis alba* and of several species of *Brassica* are highly pungent; they yield the powdered mustard of the spice-shelf and blend with turmeric and other spices in mustard pastes; they flavor salad dressings and other garnishes. The species used are annuals grown as field crops in England, China, Netherlands, Japan, Germany, and elsewhere. Some of them are common in the United States as weeds; some are cultivated in California, where they are said to have been introduced by early Spanish Fathers, who marked trails from mission to mission by scattering mustard seed. The high point of Californian production was reached during the World War, when foreign mustards were scarce.

Sinapis alba—White Mustard—is the chief source of powdered mustard, which is largely imported from England. Both this and *Brassica nigra,* Black Mustard (Fig. 335), are employed in mustard pastes, salad dressings, meat sauces, pickles, sardine-packing, etc. In both, the active principles result from the decomposition of glucosides which are broken down in the presence of water by enzymes occurring in the seeds. Black mustard yields a powerful volatile oil, allyl isosulphocyanide, which also may be made synthetically. White mustard has a pungent non-volatile oil, acrinyl sulphocyanide.

Cloves and Pimento

Cloves and pimento are from the aromatic family Myrtaceæ, a large tropical group of evergreen trees and shrubs perhaps best known in America by the exotic myrtle and eucalyptus.

CLOVES

Cloves are the unexpanded flower-buds of *Eugenia caryophylla* (*Caryophyllus aromaticus*), a native tree of the Moluccas. Their early record appears in Chinese books of the third century B.C. It is stated there that Chinese court officials, when addressing royalty, were obliged to chew cloves—possibly not an unreasonable requirement; a similar precaution is still traditionally

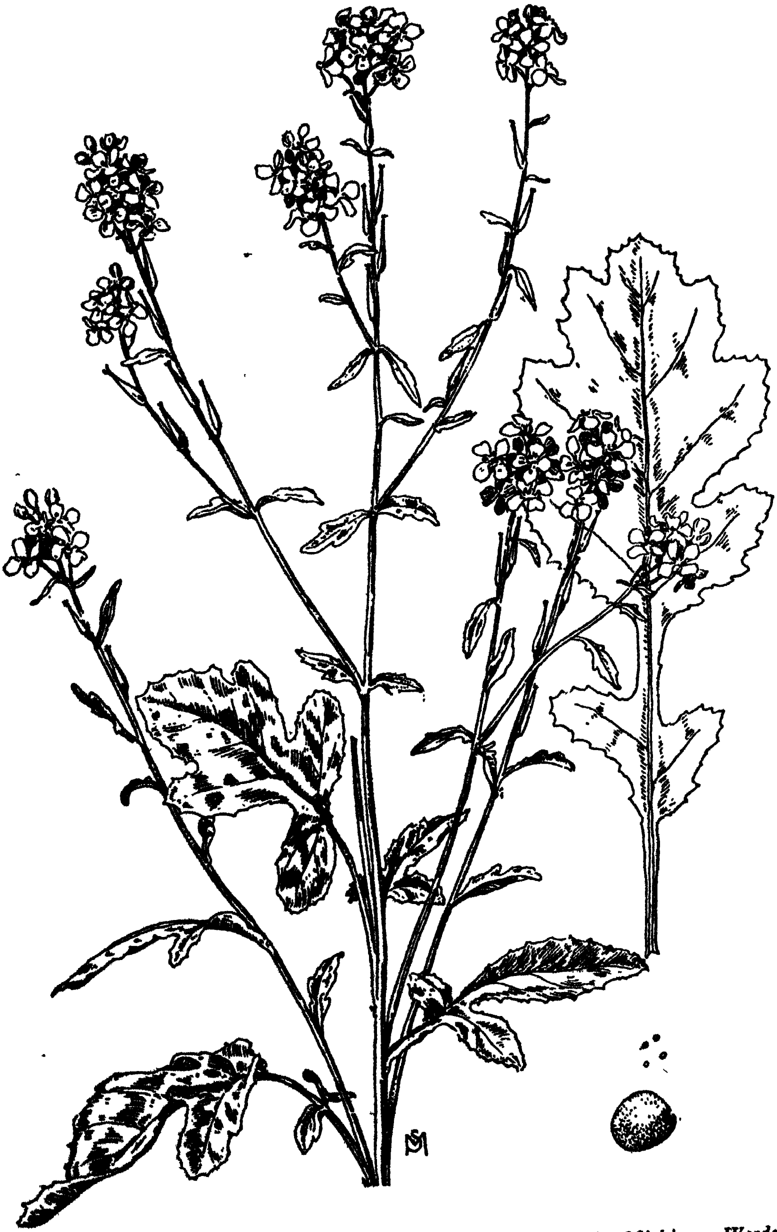

FIG. 335. — Black Mustard (*Brassica nigra*). (From Beal, *Michigan Weeds*, Michigan Agricultural College Bulletin 267.)

maintained by late-homing husbands. Marco Polo mentions cloves. The nativity of the spice was later discovered by the Portuguese, and more extensively exploited by the Dutch, who, coming into control of the Spice Islands in 1605, tried to confine clove production to the single island of Amboyna and to extirpate the tree elsewhere. For some generations the Netherlanders succeeded in monopolizing the trade, but in 1770 living clove trees were established in the French islands of Bourbon and Mauritius, and before long the tree was experimentally known in a large number of tropical regions. The British established cloves in Penang, where the industry progressed slowly at first, eventually coming into Chinese hands. Penang cloves are reputed superior to those raised elsewhere. About 1818 cloves were introduced by Arabs into the small African islands of Zanzibar and Pemba, where now this spice is the principal agricultural and trade interest. To-day Zanzibar and Pemba (together making up the British Protectorate of Zanzibar) produce seven eighths of the world's clove supply and virtually monopolize the market.

The clove tree.—*Eugenia caryophylla* is a small tree, ranging in cultivation from twelve to twenty feet, more rarely reaching forty feet in height. It is conical in shape, with gray bark; the opposite lanceolate-acute leaves unfold greenish yellow with a pinkish cast and later become dark shining green. The flowers are borne in terminal branching cymes. In the bud stage (Fig. 336) their most conspicuous member is a cylindric inferior ovary about one-quarter inch in length, surmounted by four pronglike sepals surrounding the ball-shaped investment of petals which enfolds numerous immature stamens and a single style and stigma. The buds are described as green at first, then pinkish-yellow, becoming dull blood red when ready for harvest. The flowers open pale purple; the petals fall almost immediately. The ovary develops into a dark pinkish obovate drupelike fruit about an inch in length, at the apex of which the sepals remain as triangular points.

Culture and Harvest.—The clove is said to thrive only near the sea, and practical cultivation has been only on islands. Soil requirements are exacting; sandy and waterlogged soils must be avoided. Plantings are established from seedlings shade-grown in nurseries. Trees bear at four to five years of age. Season of bud collection is rather lengthy, extending in Zanzibar from August to December. Branches are pulled down by hooked sticks and the buds removed by hand, after which they are separated from the pedicels—clove stems. The latter contain 4 to 7 per cent of oil and in seasons of scarce crop are considerably employed for distillation. In the Spice Islands the cloves may be threshed from the trees with bamboo sticks. Drying procedures vary; in Amboyna the crop is dried first by artificial heat and finished in the sun. Zanzibar cloves are sun-dried. Trees in full bearing yield from four to ten pounds of dried cloves per season.

Constituents and Uses.—Whole and powdered cloves are well known as spice. Large quantities are also used for distillation of oil of cloves; the yield is 14 to 18 per cent. The chief constituent of clove oil is about 82 per cent of eugenol. Eugenol is employed in the manufacture of artificial vanillin, and this is the principal large-scale destination of oil of cloves. The oil is also used in soaps and perfumes; being strongly antiseptic, it finds application in dental practice in killing nerves and sterilizing root canals. It is employed as a clearing agent in micro-technique.

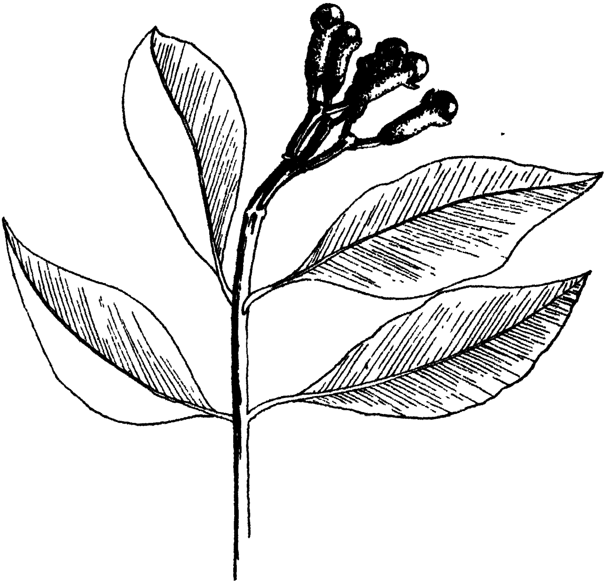

Fig. 336. — Branch and Buds of Clove, *Eugenia caryophylla*. (E. Coffman.)

PIMENTO (ALLSPICE)

This spice is commonly known as allspice, a name owed to its resemblance to a mixture of cloves, nutmeg, and cinnamon. Pimento consists of the dried nearly ripe fruit (Fig. 337) of

Pimenta officinalis, a small evergreen tree of the West Indies, now grown chiefly in Jamaica. The fruit is purple when ripe, globular, about the size of a pea, and one- or two-seeded. The pericarp of the dried spice is wrinkled and reddish brown. Trees yield about seventy-five pounds per year. Allspice is much used in pickles and occasionally in other foods. It yields 3 to 4 per cent of a volatile oil containing 60 per cent of eugenol.

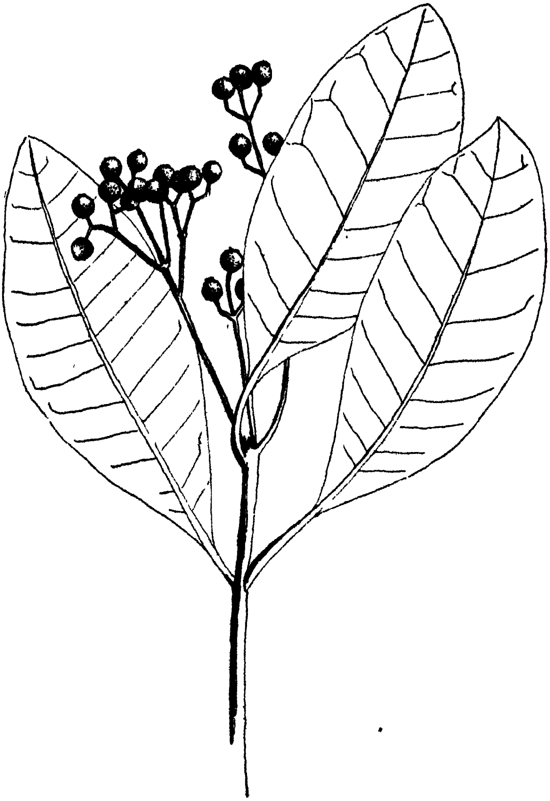

FIG. 337. — Branch and Fruit of Allspice (*Pimenta officinalis*). (E. Coffman.)

Pimento wood is employed in canes and umbrella handles.

Ginger and Its Relatives

The Zingiberaceæ, a family of Oriental perennial monocotyledons, yields several spice products, nearly all derived from thickened rhizomes. Of these ZEDOARY and GALANGAL have little appeal to the American palate. TURMERIC, esteemed in India as a yellow dyestuff as well as condiment and a prominent ingredient of curry, figures in Occidental mustard pastes. CARDAMOM, a seed product, is with us a minor medicinal; the related GUINEA GRAINS or Melagueta pepper, a prominent spice of Queen Elizabeth's day, is almost forgotten. For us, the dominant member of the group is GINGER, the prepared rhizome of *Zingiber officinale.*

The Ginger Plant.—The ginger plant is unknown in the wild state; it is probably native to tropical Asia, but where and when it came into cultivation is uncertain. The Greeks and Romans had it in trade from the Arabs, who probably got their supplies from India. Ginger scattered with developing trade; its culture was established in Jamaica by 1547, and since American colonial days Jamaica ginger has been one of the world's spice staples. Ginger is one of the most adaptable of spices. It is grown to-day in India, China, southeastern Asia, the East Indies, Australia, Africa, and in other widely scattered tropical localities. It has been experimentally produced in Porto Rico, the Philippines, and Florida.

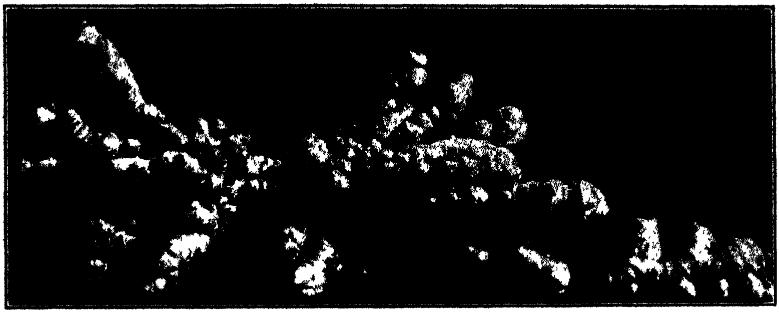

FIG. 338. — Rhizome-System of a Ginger Plant (*Zingiber officinalis*). (Courtesy of Bureau of Plant Industry.)

The stem of ginger is leafy, a yard or more in height, with sheathing lanceolate leaves and a short spike of peculiar orchid-like flowers. The fleshy rhizome (Fig. 338) somewhat resembles that of an *Iris;* its irregular branches are known as hands or races. The internal tissue of the rhizome is nearly white and starchy, dotted with resinous glands.

Culture and harvest.—Ginger is said not to form viable seed; the crop is propagated wholly from rhizome-cuttings, planted in the wet season. A light sandy loam soil is preferred. Cultivation is largely in small garden plots; the plant is handled somewhat like the potato. Harvest occurs when the leaves begin to wither, about ten months from planting. The rhizomes are tenacious of life; they are scalded before drying in order to kill buds, expedite drying, and loosen the periderm. The best gingers are peeled; as the hands are most irregular, this is a rather laborious process. Ginger is commonly sun-dried, the process taking six to eight days, during which period the rhizomes are taken in at night to avoid dew-wetting. Artificial drying is said to yield an inferior product.

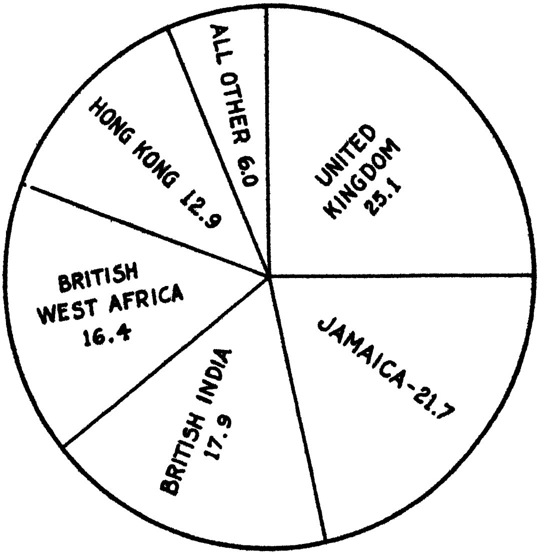

FIG. 339. — Sources of American Imports of Unground Ginger, for a Selected Year, the Total Being 3,212,000 Pounds. (From statistics by United States Tariff Commission.)

Cured ginger is liable to insect-damage, to prevent which it is sometimes limed. Liming, incidentally, tends to conceal previous damage by filling wormholes.

Jamaica ginger is considered the best; of other commercial grades known by geographical origin, Calicut, Cochin, Calcutta, and African gingers are valued in about that order.

Fig. 339 indicates the origin of American imports of ginger.

Constituents and uses.—The pungency of ginger is due to a volatile oil, a viscid principal called gingerol, and to resinous material. Ginger contains about 42 per cent starch (Fig. 340), and the powder is therefore very starchy.

Ginger is employed as a condiment and aromatic stimulant.

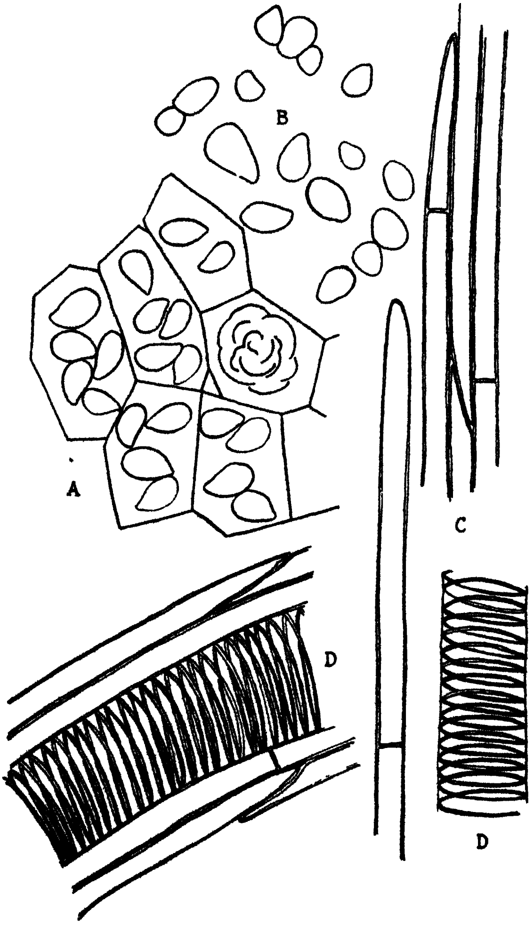

FIG. 340. — Ground Ginger. *A*, starch-bearing parenchyma, with a single resin-cell; *B*, starch granules; *C*, sclerenchyma fibers; *D*, vessels with spiral thickenings. (E. Coffman.)

Large quantities are used in ginger ale. The beverage use of the alcoholic tincture known as Jamaica Ginger has been somewhat discouraged by many cases of peculiar paralytic poisoning.

Chinese preserved ginger is made from the uncured rhizome, and the latter may be purchased in Chinese quarters of American cities. The segments often contain viable buds, from which the plant is sometimes grown as a curiosity indoors, or where winter frosts are not too severe. It is comparable to the cannas in hardiness.

Spice Imports of the United States

Statistics of these are shown in Table XVIII.

TABLE XVIII

IMPORTS OF PRINCIPAL SPICES, FOR YEAR 1928 *

Spice	*Pounds*	*Spice*	*Pounds*
Caraway	5,000,041	Mustard	15,443,216
Cassia	7,107,200	Nutmegs	3,969,136
Cloves	5,036,048	Pepper, black	22,727,716
Cinnamon	289,977	Pepper, white	4,026,313
Ginger	3,893,822	Pimento	2,211,648
Mace	672,283	Red pepper	2,818,616

* Statistics from U. S. Tariff Commission, selected as a fairly "normal" year.

These figures refer only to crude spices, unground.

2. FLAVORINGS

The flavoring EXTRACTS or ESSENCES of the market—lemon, orange, peppermint, etc., are for the most part solutions of volatile oils in more or less diluted alcohol. Most frequently used of these commodities is extract of vanilla, whose crystalline principle, vanillin, has been mentioned in connection with its synthetic production from oil of cloves.

Vanilla

The large, bizarre, widespread but mostly tropical family Orchidaceæ is chiefly celebrated for the curiosity and rarity of its blooms. Almost the sole orchid product otherwise valued is the VANILLA BEAN, the fermented and cured capsule of *Vanilla fragrans,* more generally known as *Vanilla planifolia,* a climbing orchid of Mexico and Central America. This is probably a cultivated derivative of *V. pompona,* a wild form whose inferior fruits are still a minor article of trade.

As a chocolate-flavoring, vanilla has been used by Mexican natives since prehistoric time. Spaniards carried it to Europe early in the sixteenth century. The plant was introduced in the

Buitenzorg Botanic Gardens, Java, in 1819, and within fifty years after that time vanilla cultivation was widely scattered throughout the tropics. The principal regions of success are Reunion, Bourbon, the Seychelles, Madagascar, Fiji, Tahiti, and Hawaii.

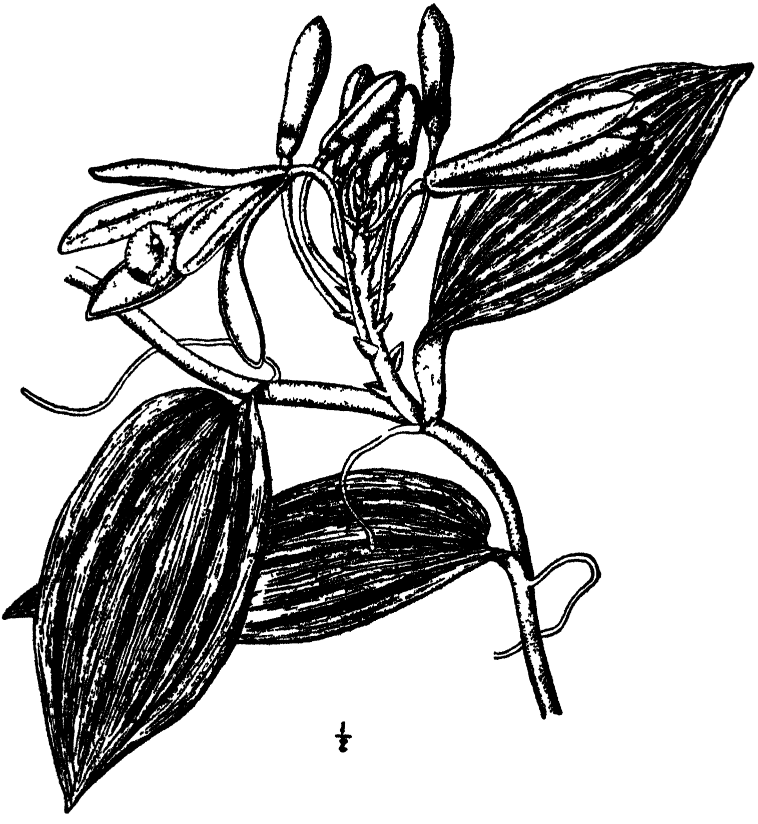

Fig 341 — Flowering Branch of Vanilla (*Vanilla fragrans*) (From Sayre, *Organic Materia Medica and Pharmacognosy*, P. Blakiston's Son & Co., Inc)

THE VANILLA PLANT

Vanilla fragrans is a perennial green-stemmed climbing plant with broad succulent ovate leaves four to nine inches long. Opposite the leaves occur white roots which twine on tree-trunks or artificially placed supports. Flowers are in bracted racemes (Fig. 341); each is about four inches long, with linear-oblong pale green perianth. One perianth segment is developed into a trumpet-shaped lip or labellum; this is rolled round a column in which the pollen-mass and the peculiarly modified stigma are separated by a projection, the rostellum. The highly modified structure of orchid flowers usually permits their pollination only by specially adapted insects. In *Vanilla,* this is usually done by certain Mexican bees and humming birds. In other regions of cultivation the requisite species are lacking and artificial pollination (Fig. 342) is necessary. This is effected by pressing up the rostellum with a small stick, removing the pollen, and thrusting it down on the stigma, on whose sticky surface it is held by the pressure of the rostellum, which springs back into place when released. This process, of course, is close-pollination; cross-pollination is more difficult and is not commonly done.

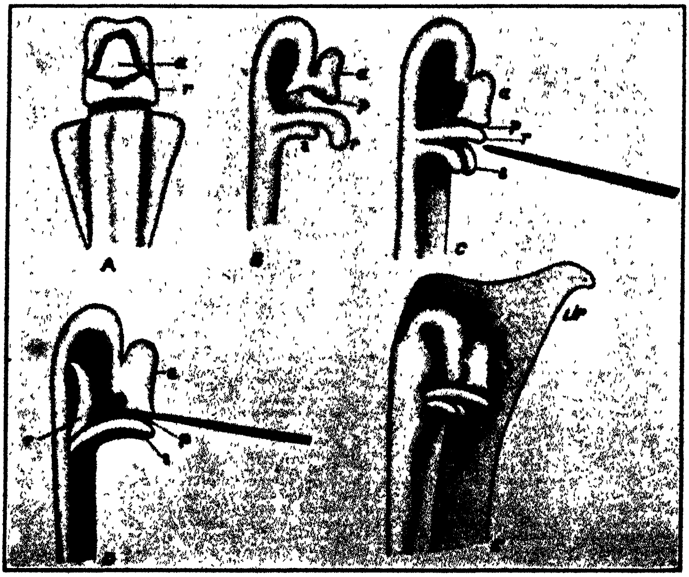

FIG. 342. — The Artificial Pollination of Vanilla. *A*, column from front; *B*, side view; *C*, side view showing position of pollenizing stick; *D*, rostellum pushed up and pollen touching stigma; *E*, side view of column showing attachment to lip; *a*, anther; *p*, pollen; *r*, rostellum; *s*, stigma. (From Ridley, *Spices*. By permission of Macmillan & Co., Ltd., London, and The Macmillan Company, New York, publishers.)

The vanilla fruit is an elongated, three-carpellate capsule (Fig. 343), with numerous and very small seed. Unlike the other miscellaneous plant products termed BEAN, the resemblance of vanilla is to the bean pod and not to the bean seed.

Culture and harvest.—The vanilla plant requires tropical climate, with frequent but not excessive rains. Outside Mexico, greatest success has been in island localities not severely windswept. In some regions, such as Malaya, heavy rains during the ripening period may dislodge pods.

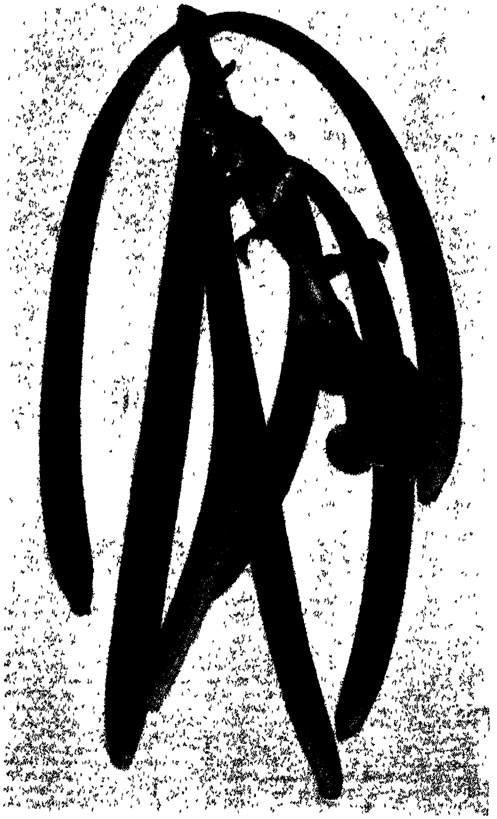

Fig. 343. — Fresh Pods of Vanilla. (Courtesy of Bureau of Plant Industry.)

The small seeds of vanilla germinate poorly, and plantations are almost invariably started from cuttings. Soil is disturbed as little as possible; even weeding is discouraged. The vines require shade, and are often trained on trees, such as cacao, from which another crop is derived; more rarely trellises are used. By the second year they reach a length of ten to fourteen feet; if allowed to climb steadily upward the vines will not flower; they are therefore trained to hang down over branches or trellises, and pinched off just before they reach the ground. The vines are quite brittle, and must be handled with care. Flowering commences the third year, and continues annually thereafter. In order to prevent overbearing only a small proportion of perhaps 4,000 blooms is fertilized. Fruit ripens in four to nine months, depending on the locality. It is harvested when still unripe but beginning to turn yellow. Ripe pods are deficient in aroma and are likely to split. After harvest the old stems are cut off, to be replaced by nature before another flowering period.

The aromatic quality of vanilla develops in the curing process, of which there are several modifications. In Mexico, the pods are piled in heaps in sheds. After partial drying for a few days, they are "sweated." In fair weather this is done by spreading the beans during the morning on woolen blankets in the sun. About mid-day the blankets are folded over the pods, and after sundown the beans are placed overnight in air-tight boxes. The process is continued for about two months. The pods become rich coffee-brown in color, and vanillin and small quantities of other aromatic products develop. In rainy periods, artificial heat is used in sweating. In the curing process in Reunion the pods are periodically dipped in boiling water.

A cured vanilla bean somewhat resembles a "kid-curler." Color and luster differ according to the curing process employed. Needlelike or threadlike crystals of vanillin may appear on the surface. Vanilla is generally packed for sale in small bundles and shipped in tight tin boxes (Fig. 344).

Vanilla is a variably priced but usually expensive product. The quality of beans from different localities may be quite different, and prices are made accordingly. Mexican beans are most highly valued; they sold for a high of $13.00 per pound in 1924, but during 1928 were quoted at $3.25. Tahiti vanilla is the cheapest grade of the American market and usually sells for a fraction of the price of Mexican. Bourbon vanilla (including the product of Madagascar and Reunion) most closely approaches the Mexican in quality; it includes about half the world output, Mexico furnishing one sixth.

CONSTITUENTS AND USES OF VANILLA

Vanilla contains from 1.5 to 3 per cent of vanillin and very small quantities of other aromatic constituents which give a genuine vanilla extract an indefinably different character from imitation products based on synthetic vanillin. Vanilla extract is obtained by percolating the crushed beans with alcohol. As previously indicated, vanillin may be made from oil of cloves or other oils containing eugenol. There are other possible syntheses of this chemical; it may, for example, be made from guaiacol, a coal-tar product. It also occurs in other plants than vanilla, though not usually in significant amount. Among plant products in which vanillin has been found are the bulbous roots of the dahlia, the seeds of a cultivated lupine, in the flowers of one of the spiræas, and in the fruit of *Rosa canina,* a European wild rose.

FIG. 344. — Measuring Vanilla Bundles for the Tins. (Courtesy of Dodge & Olcott.)

Of character somewhat similar to vanillin is coumarin, a chemical principle found in tonka beans, the seeds of certain species of *Coumarouna,* leguminous trees of Brazil and the Guianas. Coumarin, which may also be obtained synthetically, is also an ingredient of artificial vanilla extracts.

Vanilla extract is universally used as a household flavoring, as well as in ice creams, chocolates and other confectionery, and for soda fountain purposes.

3. VOLATILE OIL PLANTS AND PRODUCTS

Plants previously discussed in this chapter have, with the exception of vanilla, belonged to a fairly well-defined class of spices. Many of their constituents, as noted, are of volatile nature; and some, such as cloves and the cinnamons, are processed for their oils. In fact, the classifications of spices, flavorings, pot-herbs, volatile oil plants, perfume plants, and others that might be made, shade off insensibly into one another. While the plants to be discussed under the present heading cannot be very sharply delimited as a group, there is some justification for their separate listing. Here can be mentioned only a few of a vast variety of aromatic plants and their products.

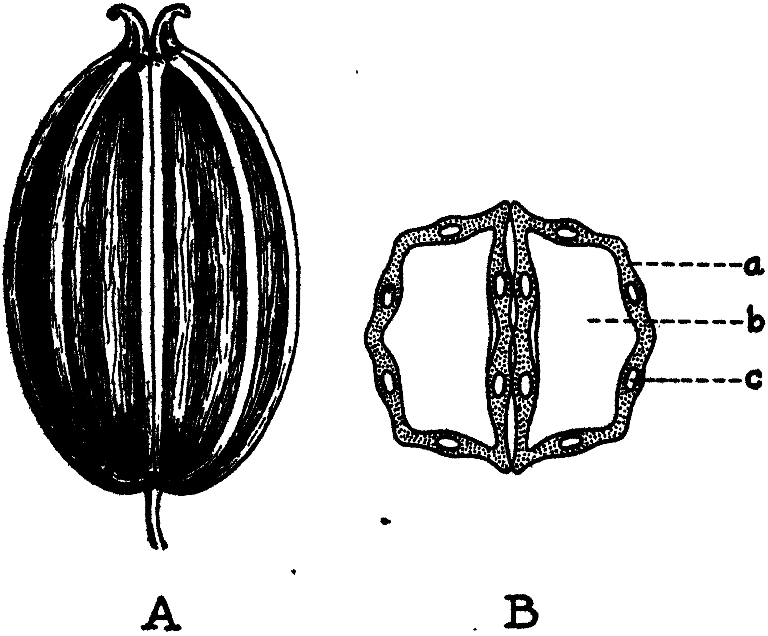

FIG. 345. — Fruit of a Member of the Umbelliferæ, the Fennel (*Fœniculum vulgare*). This type of fruit is made up of two one-seeded parts. *A*, outer view; *B*, median transverse section (*a*, pericarp; *b*, seed; *c*, oil-tube). In oil-tubes are found the characteristic aromatic products of the Umbelliferæ. (E. L. Spuller.)

The Umbelliferæ

The aromatic products of the Parsnip Family are mainly fruits of peculiar structure (Fig. 345). Plants of this group are mainly rankly growing herbaceous biennials; a few, such as the fennel, are perennials. Those principally employed for aromatic purposes include anise, caraway, coriander, cummin, dill, and fennel fruits—all of which, being small, are commercially known as seeds. CARAWAY and FENNEL are somewhat scattered in the

United States as weeds, and all those mentioned are grown somewhat on a kitchen-garden scale in this country. In Europe they are much more generally used as pot-herbs, for various culinary purposes, and for the flavoring of liqueurs, etc., than in the United States, and they are there grown as field crops. Caraway, our largest import of the Umbelliferæ (Table XVIII), comes mostly from Holland and Germany; it is familiar in rye bread and other baked products. CORIANDER, ranking next, comes from Morocco, Russia, France, and England; it finds employment in cakes and confectionery. Less commonly seen than formerly are "sugar-plums" made by covering the globular fruit of coriander with an encrustation of sugar. CUMMIN, used by immigrants as soup-flavoring and for various other purposes, is from Mediterranean islands, France, and northern Africa. FENNEL (Fig. 345) is from southern Europe and Germany and ANISE mainly from Spain. In aromatic qualities these two are almost identical; they are employed in confectionery, licorice flavoring, etc., and distilled for their oils, which are medicinally employed. Most of the products listed above, in fact, have had some medicinal use, particularly in foreign practice and in home remedies, but they are practically obsolete in modern therapy.

The Labiatæ

This group, the Mint Family, is one of the most celebrated of volatile oil families. Here are listed peppermint, Japanese peppermint, spearmint, lavender, pennyroyal, rosemary, marjoram, catnip, and many others.

PEPPERMINT

The peppermint plant is *Mentha piperita*, a cultivated European plant which has become naturalized in moist places almost throughout the United States. It is perennial, with long-running rhizomes or stolons, which are used for propagation, viable seed not being formed. The stems, like those of most other mints, are square in outline, with serrate oval short-petioled leaves in opposite pairs at each node. Small purplish, nearly regular flowers, are borne in dense terminal spikes and upper axils. Two varieties occur: White Mint, with green stems and light green leaves, and Black Mint, with dark purple stems and darker leaves. White mint yields a fine grade of oil, but, being less hardy and productive than the black, is scarcely grown in this country. Oil of peppermint is formed in glandular hairs of the leaves.

Peppermint culture began in Wayne County, New York, about 1820. It soon spread westward into northern Ohio, Indiana, and southern Michigan (Fig. 346). There it has attained its principal development in the level, rich muck of prehistoric lake bottoms. More lately it has been tried in muck lands of Oregon, Washington, and California. In all these regions the crop is grown on a field-and-machine scale and distilled, generally, with up-to-date and efficient apparatus. Harvest is at blooming time; in the West, two crops a year may be obtained. Next to the turpentine industry, which from point of view of operation, character, and use of product is in quite a different class, peppermint oil production is the largest essential oil interest of the United States, with an annual output of 350,000–400,000 pounds from about 33,000 acres. Peppermint oil is reckoned rather a speculative product; in some years large profits

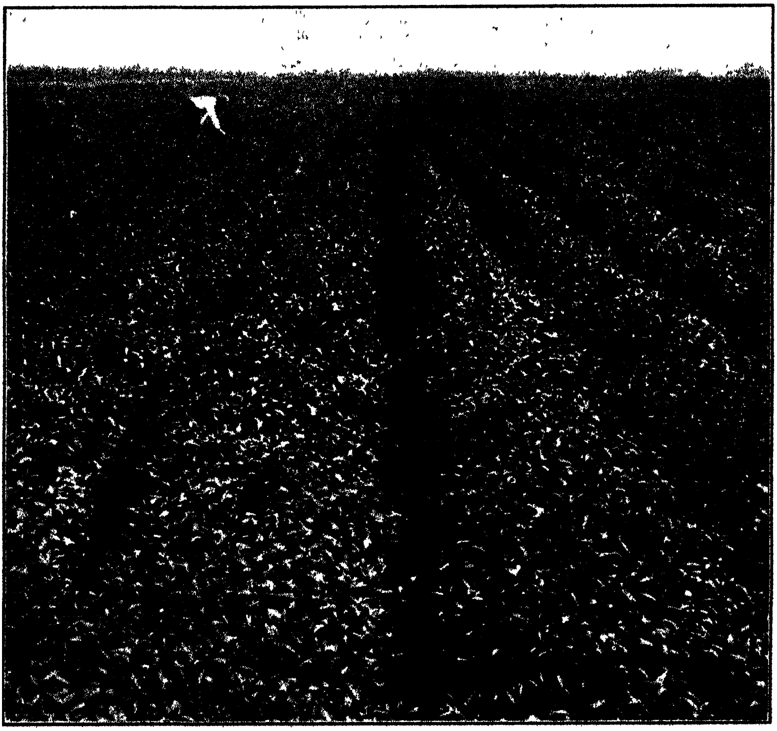

FIG. 346. — A Peppermint Field in Michigan. (Courtesy of Bureau of Plant Industry.)

have been made; in others, oversupply has disastrously broken the price. The oil is also distilled in England, Germany, and France.

Peppermint oil contains 50 to 78 per cent of a crystalline principle, menthol, and 5 to 20 per cent of menthol esters. It is used mainly in chewing gums, confectionery, pharmaceutical preparations, tooth pastes, household essences, etc.

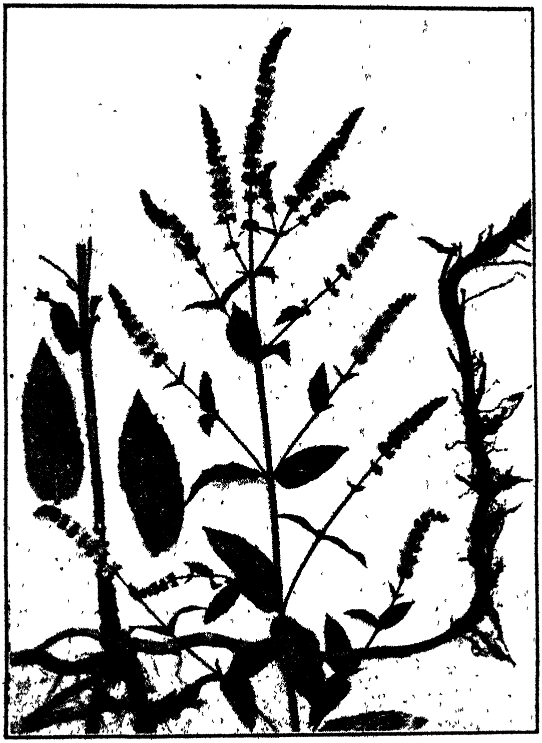

FIG. 347. — Spearmint (*Mentha spicata*). The underground stems shown below and at the right are typical of the mints. (Courtesy of Bureau of Plant Industry.)

JAPANESE PEPPERMINT

This is a somewhat different plant, *Mentha arvensis* var. *piperascens*, which is grown extensively in northern Japan. It yields a rather bitter oil, containing 65–85 per cent of menthol, and is employed almost wholly for the recovery of that principle.

Menthol is used in throat and nasal sprays, cough drops, liniments, etc. Synthetic menthol is made from various sources.

SPEARMINT

This plant, *Mentha spicata* (Fig. 347), is cultivated in the mint regions of the United States; the crop is said to be about 10 per cent as great as that of peppermint. The oil, which contains about 65 per cent of carvone, finds employment mainly in chewing gums.

Perfume Oils

These are mainly but not wholly obtained from flowers. Many "floral" perfumes, however, are based on skilfully blended mixtures of organic chemicals derived most indirectly from plant origin through coal tar, and including, perhaps, fractions of various volatile oils not mentioned on the labels. Production of flower perfumes centers largely in southern France, in the regions of Grasse, Cannes, and Nice. In these sunny lands originates the famous French supremacy in perfumes and cosmetics.

ROSE OIL

As an interesting example of a perfume oil may be chosen rose oil, also known as attar or otto of rose. Rose oil is made from only a few of the many kinds of roses. *Rosa damascena* of Bulgaria is the principal source. Production is mainly in Bulgaria; from that country it has spread to southern France, tropical French possessions, Germany, and Spain. The following account is based on the Bulgarian industry, which centers in the mountainous region around Kazanlik, where the roses are cultivated by the peasants. The blooms are gathered only in the early morning and must be distilled within twenty-four hours, otherwise the quality of the oil suffers. Stills are most primitive; the vats consist of large copper vessels three to five feet high. In these are placed about twenty-five pounds of rose flowers and eighty-five liters of water. Boiling continues until about ten liters of water has distilled over, carrying with it the oil. The spent flowers are removed, and more thrown in the same hot water. The process is repeated till about forty liters of the distillate—rose water—has collected. The rose water is redistilled in a separate still; the oil is separated from the first five liters of the resulting distillate and the remainder is returned to the first still.

In France and Germany more modern stills, in which live steam is led through the flower-mass, are employed.

From 3,500 to 4,200 pounds of roses are required for one pound of rose oil. There are about 200 roses to the pound; thirty roses yield about one drop of the precious perfume-base, whose value ranges around $40.00 per pound. Because of the high price of attar of roses, adulteration is not uncommon. It has been pointed out that in some years Bulgarian exports noticeably exceed production figures, and that considerable quantities of palmarosa oil, a much cheaper product used for adulteration, are imported by Bulgaria.

France is the chief consumer of attar of roses. Annual imports of the United States average about 56,000 ounces a year.

French roses are largely used in floral waters, pomades, cosmetics, etc.

CITRONELLA AND LEMON-GRASS OILS

The largest perfume oil importations of the United States are of citronella and lemon-grass oils, distilled from certain grasses of Ceylon, Malaya, and Java, and used in soap perfuming, in mosquito repellents, in furniture polishes, and for various other purposes. Imports statistics of these oils are combined; they run about 1,400,000 pounds per year.

PERFUME EXTRACTION PROCESSES

Some perfume oils are extremely delicate; their aroma is injured by the hot water or steam used in distillation processes. Such oils may be obtained by EXTRACTION, ENFLEURAGE, or MACERATION. In the extraction processes the flowers are treated with some volatile oil solvent which boils at a low temperature—alcohol, benzine, or petroleum ether. The solvent is later removed from the extract by distillation.

When even the low degree of heat required to distil petroleum ether is undesirable, or when a pomade or "concrete" is desired, enfleurage is employed. A layer of flowers is spread on a wire netting, and directly above is suspended a glass plate smeared with fat, such as lard, or heavy oil. Flowers and plates are placed in alternate layers and allowed to remain for a number of days. Spent flowers are removed and new ones added from time to time; when the fat is well saturated with the odorous constituents of the flowers, it is washed with alcohol, which extracts most of the perfume. Some remains in the fat, which is used in making perfumed toilet soaps. Jasmine and tuberose are usually treated by the enfleurage process.

Maceration is allied to enfleurage; it is commonly used for violet, rose, orange, and cassia flowers. The bruised flowers are mixed with warm lard or oil, which absorbs the odor.

FIG. 348. — Camphor Tree (*Cinnamomum Camphora*). Courtesy of Bureau of Plant Industry.)

Camphor

Camphor is a crystalline compound of the formula $C_{10}H_{16}O$ or $C_9H_{16}CO$. It is derived from the wood or leaves of *Cinnamomum Camphora* (Figs. 348 and 349) of the Lauraceæ. This is a round-headed, handsome evergreen with light green foliage, somewhat introduced into California and the South for shade.

THE CAMPHOR TREE AND ITS PRODUCT

The camphor tree occurs in Formosa, Japan, and southern China; about 77 per cent of the world's camphor forests are in

Formosa. The Japanese Government, which took Formosa from China in 1895, exercises a virtual monopoly of natural camphor production, which it has employed in times past to great profit. The original process of camphor production was most wasteful, and no care was taken to insure future supplies. The entire tree was cut, reduced to small chips, from which the camphor was distilled from boiling water in crude stills. The pinkish granular crude camphor contains about 20 per cent of a liquid oil of camphor. This may be removed by further distillation, and the camphor refined by sublimation. Oil of camphor consists largely of safrol; it is closely allied to the American oil of sassafras, for which it has been substituted in soaps and perfumes.

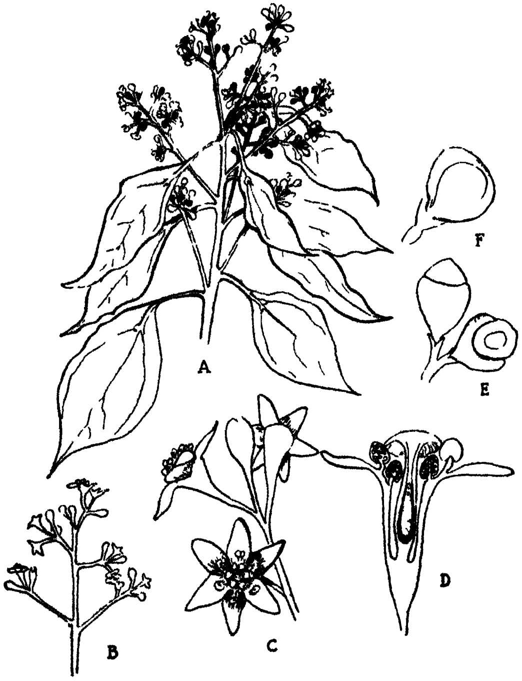

FIG. 349. — *Cinnamomum Camphora* *A*, flowering branch; *B*, *C*, details of inflorescence; *D*, flower in median longitudinal section, *E*, *F*, fruit. (H. McCarthy.)

The actual collection of camphor is done mainly by Chinese and semi-savage Formosans under the sharp supervision of the Japanese, In late years provision has been made for future supplies by compelling the planting of a young camphor tree to replace each one cut down.

The high profits of the camphor monopoly have prompted attempts at camphor production elsewhere, as in India, former German colonies in Africa, and in Florida. Little success has been attained. In Florida the camphor tree is grown in tall hedges, sheared by machinery, and the leaf-and-stem clippings distilled.

SYNTHETIC CAMPHOR

More potent as a recent check on Japanese monopoly has been the synthesis of camphor from oil of turpentine. The formula of the latter, $C_{10}H_{16}$, might afford an erroneous impression of the ease of a process which is in fact extremely intricate. Several modifications of an ingenious but expensive manner of attaining this synthesis have long been known, but commercial production in the United States has been mainly confined to the years from 1917 to 1922. Germany, under even greater war-time need, perfected a camphor-process whose operation has since been continued. German synthetic camphor is now an important rival of the Formosan natural product.

USES OF CAMPHOR

Camphor is mainly used in the manufacture of pyroxylin plastics—mixtures of nitrocellulose and camphor, known by a variety of trade names. Celluloid was one of the first forms introduced, and the name is loosely used to cover more recently developed and less explosive plastics. Camphor is well known as an insect-repellent. Natural camphor is used in pharmaceuticals and liniments. Camphorated oil, or camphor liniment (not to be confused with the oil of camphor mentioned above) is a 20 per cent solution of camphor in cotton-seed oil.

CHAPTER XV

BEVERAGE-YIELDING PLANTS

Water and milk are the most natural beverages of mankind. Without water, in fact, no drink would be potable. If the great American class of "soft drinks" be left out, the beverages of the world divide themselves mainly into two classes; those in which the yeast plant has degraded sugar into alcohol, and those brewed from plant products in which nature has deposited caffeine or its derivative, theobromine. While yeast and sugar are omnipresent in nature, the tropical tea, coffee, and cacao plants were originally of localized distribution; their world-wide use has grown up in the last few centuries with the development of commerce and transportation. Alcoholic beverages, for various reasons, are beyond the purview of this text. To the second class of drinks, some attention may be given.

Caffeine and Its Analogues

Caffeine is a basic substance, commonly classed as an alkaloid, to which is assigned the formula $C_5HN_4O_2(CH_3)_3$. It occurs in a scattered assortment of plant products. The best known of those which yield it in significant amount are coffee and tea. Cola, guarana, yerba maté, and other minor caffeine products supply this gentle stimulant in various parts of the world.

Medical authorities class caffeine as a diuretic and cerebral stimulant; in the latter condition it imparts mental animation and wakefulness. The physiological significance of the use of caffeine beverages is a moot point; the consensus of medical opinion seems to be that they may easily be overused, particularly by the young. Caffeine, and also the sugar used in most preparations of it, produce a sensation of dryness in the throat. and as a result one drink is likely to lead to another. While cocoa and chocolate have considerable food value, that imparted to water by infusion of tea, coffee, or caffeine itself is negligible. For diuretic uses caffeine tends to be replaced by the related substances, theobromine, found in cocoa, and theophylline, a minor constituent of tea, which are more efficient with less cerebral effect.

Analyses show that caffeine is largely used in certain soft drinks.

The most commonly known commercial source of caffeine is tea waste and sweepings, of which from three to five million pounds are shipped to this country after being denatured with lime to prevent beverage use. This material contains about 2 per cent of caffeine. Theobromine is derived from cocoa waste, which contains 1 to 1.5 per cent. Caffeine may be derived from this; amounts thus obtained are now said to exceed those separated from tea. Theophylline, which occurs in tea in very small quantity, is also made from theobromine.

The significance of these substances in the metabolism of plants in which they occur is quite problematical.

Coffee

HISTORY

Beverage coffee is derived from the seeds of *Coffea arabica* and a few other minor species of *Coffea,* of the Rubiaceæ. Despite its specific name, the common coffee tree is probably Abyssinian in origin, though it seems to owe its beverage use to Arabs, who, at some uncertain time prior to the fifteenth century, brought it into cultivation in the Yemen province of Arabia. Moslems found in the new drink an effective stimulant to wakefulness during long religious rituals. Its use, though at first stoutly opposed by the more orthodox devotees of a creed which bars alcoholic stimulants, soon spread throughout the world of the Prophet. The limited output of genuine Arabian Mocha is still consumed almost wholly by the Faithful, although the term "Mocha" is in use for certain types of coffee raised elsewhere.

The Arabian beverage came into Venice in 1615, and thence moved westward, slightly preceding tea. Culture of the coffee tree began in Ceylon, India, and Java about 1690. These regions ruled the coffee world till the 1870's, when one of the great plant plagues of history, the Rust Leaf-blight (*Hemilæa vastatrix*), ruined in a few years the great coffee trade of the British Orient, making way in the devastated regions for cinchona, rubber, and later, tea. A little coffee for which the highest quality is claimed, is still produced in India. Javanese coffee culture persists more vigorously, making use of blight-resistant strains.

Coffee has migrated experimentally all over the agricultural tropics. It came to the West Indies in 1720, and to Brazil fifty years later. There is a tradition, perhaps a doubtful one, that all the vast coffee development of the New World came from two trees which alone survived an original French shipment to the West Indies. Coffee is now tremendously localized in southern Brazil, where an area only a fraction of the size of Ohio produces about 60 per cent of the world's 3,000,000,000 pound crop of coffee. Other major producing areas are indicated in Fig. 350. Of our own tropical possessions, Porto Rico leads with a crop of over 26,000,000 pounds, nearly all of which goes to Europe. We import 2,000,000 to 3,000,000 pounds from our Pacific territory, Hawaii.

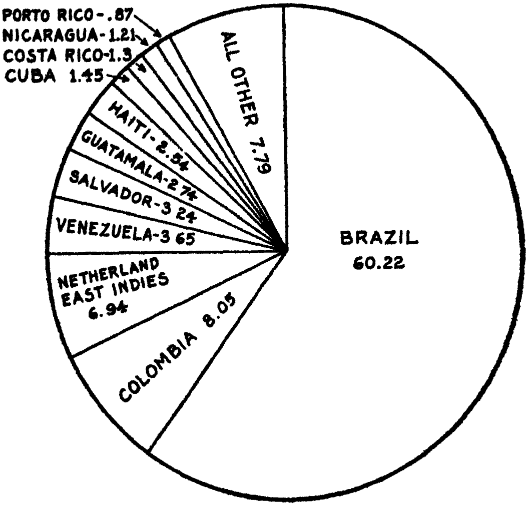

Fig. 350. — Sources of the World Production of Coffee. The whole is estimated at 3,108,266,000 pounds. (From statistics by United States Tariff Commission.)

THE COFFEE PLANT

Coffea arabica (Fig. 351) is a small, beautiful evergreen of the Rubiaceæ, a family otherwise of little significance save for *Cinchona* and quinine. The ovate leaves are opposite and glossy green; the flowers five-parted, snow-white and starlike, delicately fragrant and ephemeral, borne in axillary clusters. They appear at intervals of about a month three or four times a year. The fruits, known as coffee cherries, are about half an inch long. A deep crimson SKIN or epicarp surrounds a yellowish pulp;

within this, invested by a cartilaginous PARCHMENT and a delicate SILVER-SKIN are the two seeds, the coffee BEANS (Fig. 352),

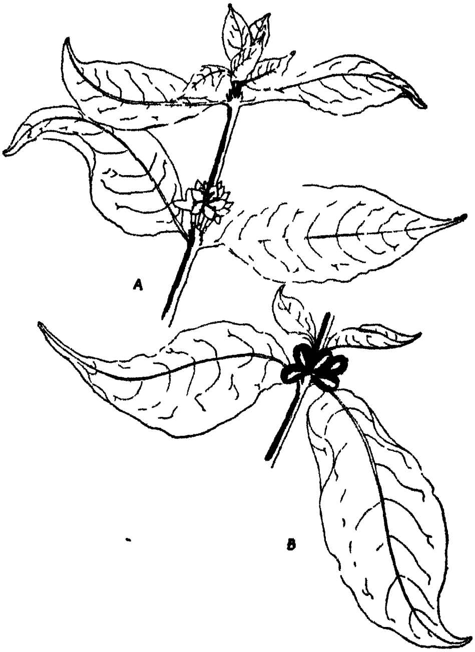

FIG. 351. — Coffee (*Coffea arabica*). *A*, branch with leaves and flowers; *B*, portion of branch with coffee "cherries." (E. Coffman.)

each ellipsoidal and flattened and creased on its inner surface. In PEABERRY coffee, only one globular seed develops.

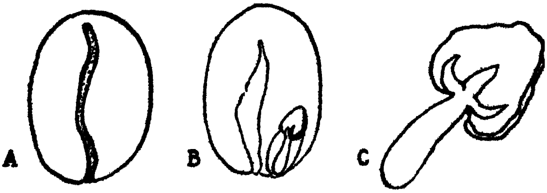

FIG. 352. — The Coffee "Beans." *A*, outside view; *B*, sectional view showing position of the embryo; *C*, embryo. (H. McCarthy.)

Some other species of *Coffea* are of minor importance. *C. liberica* and *C. robusta* are inferior to *C. arabica* in quality, but they are more blight resistant. They are grown to some extent in Africa, Java, and elsewhere in the Orient and have been used for hybridizing with *C. arabica.*

Culture and harvest.—The climatic and soil requirements of this crop are rather exacting. Coffee is a tropical tree and will not stand heavy frosts. It finds its best development, however, on the margins of the tropics where insects and diseases are somewhat less troublesome. It is favored by hill-slopes where both soil and air drainage are good, and by rich volcanic soil with abundant iron and potash. The crop should mature during a dry season, in which the fruit may be air-dried. All these conditions are fulfilled almost to perfection in southern Brazil in the state of São Paulo, inland from the great coffee ports of Santos and Rio de Janeiro.

Coffee trees are started from seed, and usually are shaded at least till well established. In large plantations, they are usually transplanted from nurseries. Bearing begins about the third or fourth year, and full yields develop at from seven to ten years. The trees are headed to fifteen or sixteen feet to facilitate picking, and the limit of profitable production is about thirty years.

Like most fruit-crops, coffee requires a vast amount of hand labor. Here only is the Brazilian at a disadvantage in competition with the Far East; on many of the great plantations literally thousands of laborers are required during the picking season (Fig. 353); and the planters, often caught short-handed, look longingly toward the teeming cheap-labor regions of China and Java.

In the Orient, coffee cherries are picked mainly by hand; in Brazil, where help is higher and coffee lower, sheets may be spread on the ground. Upon them fall masses of cherries, twigs, and leaves, all stripped off at once by recklessly hurried fingers. Separation of cherries from leaves and other debris is in flumes or streams of running water; the ripe cherries sink, while dried ones and trash float away. The pulp of the fruit is removed by machine processes, after which the seeds, damp and still invested in parchment and silver-skin, undergo a partial fermentation. They are then dried in sun—or by artificial heat if sun fails—and divested by machines and winnowing from parchment and silver-skin, traces of which may remain in the crease. By the older and almost obsolete dry process of Arabia, the entire cherry was sun-dried and the seeds later recovered. After sufficient drying, the raw coffee is shipped in large sacks to countries of consumption, where it is roasted for use. There is considerable variation in flavor and aroma of different types of coffee, for which varietal differences, climatic influences, methods of production and curing, and different roasting procedures, are

FIG. 353. — Native Girls on a Coffee Plantation in Guatemala. (Courtesy of Pan American Union.)

responsible. Most brands of coffee on the market are blends of different kinds.

Coffee is the major agricultural, commercial, and revenue article of Brazil. Like many other large single-product areas, this

South American republic has in recent years suffered from overproduction in its main industry. Attempts have been made to control the situation by restriction of planting, production, and output—all of which are considered in what is known as the Valorization Scheme of stabilization—and by burning surplus coffee, some of which has replaced coal on Brazilian railways.

CONSTITUENTS OF COFFEE

Roasted coffee contains 1 to 2 per cent of caffeine and larger quantities of glucose, dextrin, fatty oil and protein. The aroma is attributed to an oily substance called caffeol. In the presence of air caffeol tends to disappear and the fatty oil to become rancid soon after roasting; therefore vacuum packs for high-grade coffee have recently assumed prominence. Tannins or tanninlike substances have been reported in coffee, but recent investigations indicate the amount of true tannin to be negligible.

USE OF COFFEE

Coffee slightly preceded tea and chocolate into Great Britain. While in Oriental use neither tea nor coffee is sweetened, the two drinks shared in introducing the large-scale use of sugar into the Occident. In the coffee houses of France and England in the seventeenth century gathered the wits and celebrities of the time, to the considerable unease of the suspicious monarchs, Louis XIV and Charles II. In America, coffee gained headway more slowly; the use of it in Colonial days seems to have been small. The first American coffee mill was built in New York in 1833. To-day, however, the United States consumes about half the coffee of the world. Our per capita consumption of twelve to thirteen pounds per year is exceeded by that of the Scandinavian countries and by Holland. The latter, using about sixteen pounds of coffee per person per year, should house the world's largest coffee pots. The other great Anglo-Saxon nation prefers tea; outside of the Dutch in South Africa, the white population of the British empire uses only about a pound of coffee per capita per year.

Sources of our American imports of coffee are shown in Fig. 354.

Coffee is solely a beverage product. A little caffeine is obtained as a by-product of the roasting industry. While the caffeine content of the coffee bean is usually below that of the tea leaf, much more coffee than tea is usually used per cup, and the processes of preparation tend, perhaps, to more complete extraction. Reckoning forty cups to the pound, the caffeine content of a cup of breakfast coffee should be about two grains. The medicinal dose of the alkaloid is two and one-half grains. For those who fear the "drug" effect, decaffeinized coffees have been developed and cereal substitutes exploited. Efforts have been made to show that deleterious effects experienced by some coffee drinkers are due to faulty methods of preparation and to constituents other than caffeine.

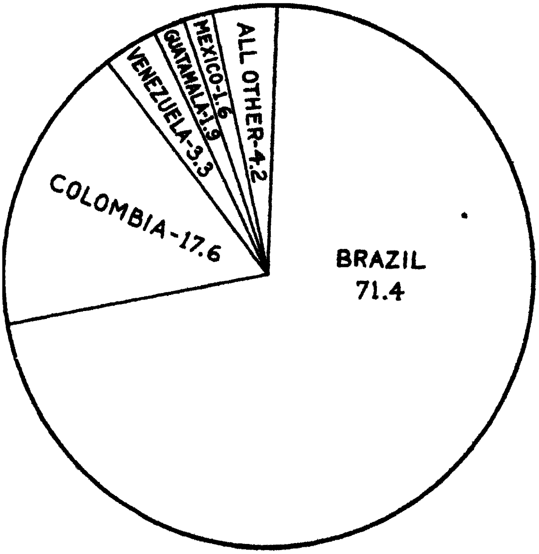

FIG. 354. — Sources of American Imports of Coffee, for a Selected Year. The total is 1,333,322,000 pounds. (From statistics by United States Tariff Commission.)

Tea

HISTORY

Tea is the leaf of an evergreen bush, *Thea sinensis* (Fig. 355) of the Ternstrœmiaceæ. The tea plant has been found growing wild in Assam, and is probably native also to some portions of China and Japan. Chinese tea cultivation began in prehistoric times; while in the popular mind the leaf is as much Japanese as Chinese, its use in the archipelago seems to have begun about the comparatively recent date of 805 A.D. In their early trade with China and Java the Portuguese met with tea, but they seem to have been little impressed by it. The Dutch, later acquiring the territories to which the Portuguese had helped themselves, learned the use of tea from Chinese in Java and brought the leaf to Europe about 1610. The year 1658 is usually stated to have seen the introduction of tea into England, although there is some evidence that it may have been there somewhat earlier. Although the great popularity of tea in England is more recent than generally supposed, the drink gained rapidly in favor both as a luxury and as an article from which revenue might be derived. In America, tea and its taxing assumed something like the political importance of alcohol in a later century. No American Colonial history omits the Boston Tea Party.

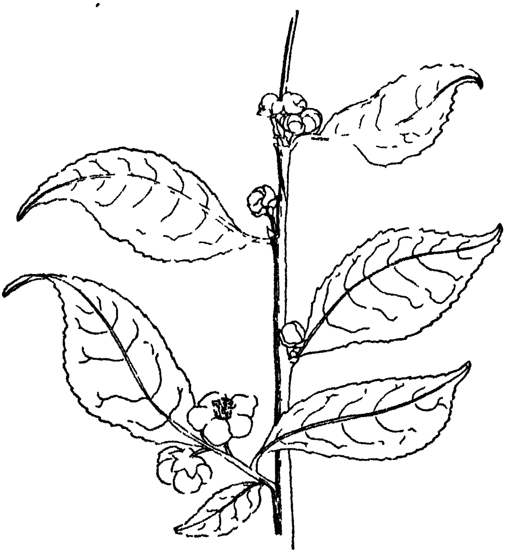

FIG. 355. — Leaves and Flowers of Tea (*Thea sinensis*). (E. Coffman.)

Tea played a prominent part in the opening of the Orient to Occidental commerce. From 1677 to 1834 importation of tea to England was a monopoly of the East India Company, whose supplies came indirectly from China through Java and India and later from China direct. Company agents early tried to introduce tea growing in India, but the first auction of tea raised there took place in 1840, after the abrogation of the monopoly. Throughout the latter days of sail—the days of "wooden ships and iron men"

—the tall East Indiamen ran home, first round the Cape and later through the Suez Canal, vying in speed to save the volatile fragrance of the precious leaf.

Javanese tea culture, started in 1826, assumed important proportions only slowly. Chinese in Formosa cultivated tea about 1860. Large-scale production in Ceylon succeeded the coffee leaf disaster in the 1870's. Experimental production of tea has been attained in widely scattered tropical and semitropical localities, including South Carolina in the United States. Here, thus far, no machine device has been able to compete in cost with the coolie and ryot fingers of the Far East. As indicated in Fig. 356, China leads in world production, but not more than 10 per cent of its estimated crop is exported, while probably 90 per cent of British Indian and Ceylonese tea, half that of the Dutch East Indies, and one third the leaf of Japan, enters the world market.

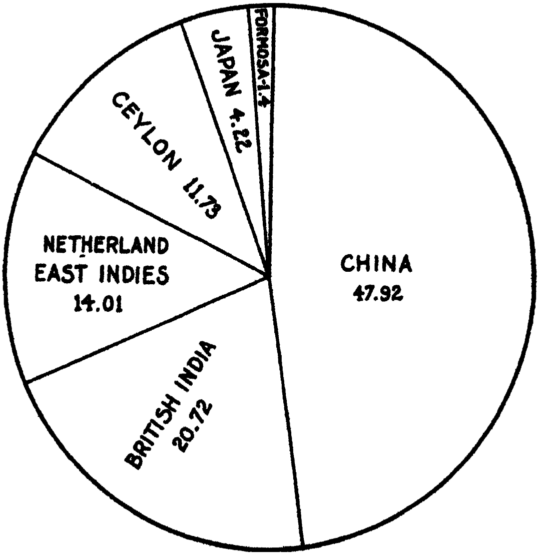

FIG. 356. — Sources of the World Production of Tea. The whole is estimated at 1,764,000,000 pounds. (From statistics by United States Tariff Commission.)

THE TEA PLANT

In cultivation, *Thea sinensis* becomes a much branched bush or hedge-plant; in the wilds of Assam it is a fair-sized tree. Leaves are alternate, elliptical or lanceolate, serrate and short-petioled. At maturity they are coriaceous and two to five inches long. For beverage purposes, young leaves are picked. Flowers occur in small axillary groups or solitary; they are white, slightly fragrant, with five to nine deep-cut corolla lobes, the whole one to one and one-half inches across. Numerous short stamens occur in two series; the single pistil is three-carpellate with three style branches. The fruit is a woody capsule with a large globose seed in each cell. Several tea varieties are in cultivation.

Tea culture and harvest.—The tea shrub requires heavy rainfall; that of the principal districts of culture ranges from 90 to 200 inches. The plant is grown in open fields or terraced hillsides, direct from seed or from nursery stock. In Ceylon and India it is grown on tremendous plantation scale; the product of China is from small patches round homesteads. The first leaf-crop is taken at three years; the shrub is in full bearing at six, and may be cropped for fifty years or more. The number of annual pickings varies considerably in different localities. Several times through the year, the shrub shows sudden and vigorous growth—the flush (Fig. 357). The principal pickings are made from these young shoots. In China, three pickings are usual; in Japan, three or four; in India and Ceylon tea may be picked ten to twenty-five times a year. Picking is by hand; scissors, with a basket attachment below the blade, are in use in some regions. This hand-work is the chief expense of tea raising, and cheap labor as much as favorable climate is responsible for the present localization of the crop.

TYPES OF TEA

Teas come into trade under a variety of vernacular names; most of them may be classified as BLACK, GREEN, or BRICK. The color-terms refer to the appearance of the dried leaf. Black tea draws a rich orange; green tea, a pale greenish yellow liquor. While, as previously stated, there are a number of fairly distinct varieties of the tea shrub, the distinctive characters of finished teas are due mainly to method or preparation of the leaf and to its age and quality. India and Ceylon are the principal sources of export black teas. After plucking, which is mainly done by women and children, the branch-ends with their leaves are spread and allowed to wilt for eighteen to thirty hours under careful supervision. When the right stage is reached, they are passed through machines which roll and more or less crush the flaccid leaves, breaking cells and setting free oxidizing enzymes. The fermentation which follows this is primarily an oxidation.

This goes on as the rolled leaves lie for a few hours in a cool place in layers an inch or two thick. After fermentation the tea is briefly rolled again and hot-air dried to crispness at about 240° F. Mechanical sorting and sifting then takes place. The grades, in order of quality, are Orange Pekoe, Pekoe, Pekoe-Souchong, Congou, and Dust. Orange Pekoe is composed of the smallest leaves of the bud; in the green stage these are covered with a fine gray pubescence which becomes orange in the curing process. While still warm, the sorted tea is packed and sealed in lead-lined cases for export. This sealing conserves the freshness and the bouquet or aroma of tea, which are rather evanescent in air.

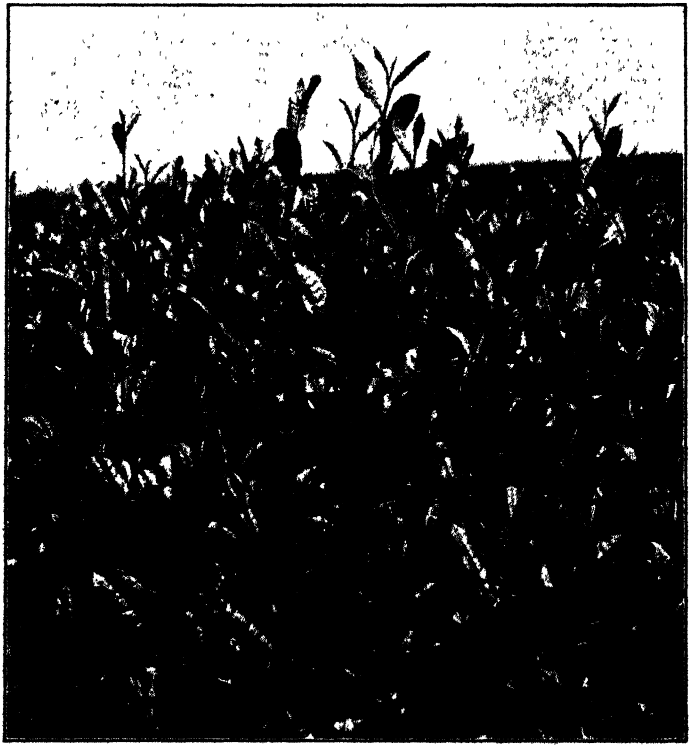

FIG. 357. — The Flush or Young Growth of Tea Leaves. For the best teas, only the three top leaves are picked. (Courtesy of Japan Tea Promotion Committee.)

In the American mind, green tea is associated with Japan, from which our supplies are mainly derived (Figs. 358, 359). Directly after picking, Japan tea is steamed; this destroys the oxidative enzymes and helps to develop the aroma. The steamed leaves are rolled and dried, usually by a series of machines; they are then known as raw or natural leaf. Pan-fired and basket-fired teas are made from raw leaf by re-drying in iron pans or bamboo baskets over artificial heat. After the final drying, the teas are sieved, winnowed, and packed. The finest Japan teas are Gyokuro—"gem of dewdrop"—and Tencha. Both of these are shaded teas, being made from very tender leaf-buds which are grown under temporary shade. Tencha is ground into powder—Matcha—for the famous Japanese tea ceremony. Shaded tea is almost wholly consumed in Japan. Unshaded tea—Sencha—includes export tea as well as that for ordinary consumption in Japan. Bancha is the tea from coarser, older leaves.

Fig. 358. — Interior of a Japanese Raw Leaf Tea Factory. (Courtesy of Japan Tea Promotion Committee.)

Japan produces about 100,000,000 pounds of green tea annually, of which about 20 per cent is exported to America, the principal market.

Formosan tea is called Oolong; it is slightly fermented before drying, and is midway in character between black and green tea. Oolong exports go chiefly to the United States.

Black, green, and brick tea are produced in China. In that country tea is grown in small household patches, picked and sun-dried by the owners, and further processed by middlemen. Rolling and handling are largely done by hand. Some of the finer Chinese teas are scented by exposure to the odor of flowers. Mainly for this purpose, a million dollars' worth of jasmine flowers are grown annually in the province of Foochow.

In some years, black tea production predominates in China; in others, green teas lead. Chinese teas are known by a multitude of vernacular names. Green tea grades are Young Hyson, Hyson No. 1, Hyson No. 2, Gunpowder, and Dust. Brick tea is usually made of dust or inferior tea, compacted with glutinous material into rectangular blocks. Brick tea goes to Tibet and Russia.

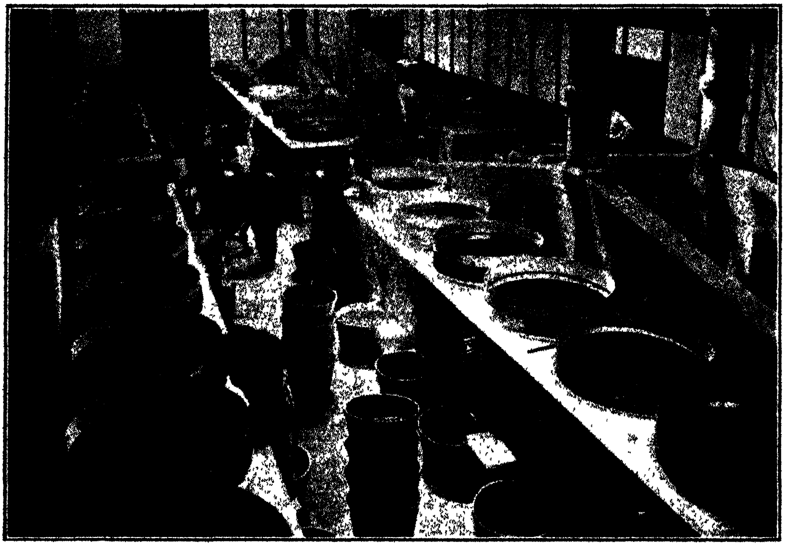

Fig. 359. — Pan-Firing. The raw leaf is fired in iron pans fixed on brick furnaces for 30 to 40 minutes, being stirred meanwhile by a propeller-like paddle. (Courtesy of Japan Tea Promotion Committee.)

CONSTITUENTS OF TEA

Tea contains 1 to 3 per cent of caffeine and a very small amount of the allied alkaloid theophylline. Recently, advertising claims have been made as to the richness of green tea in vitamin C. This vitamin probably occurs in all green leaves; considering the very small amount of actual plant substance in a cup of tea, it seems improbable that the vitamin content is of any dietary significance.

USE OF TEA

The first use of tea leaves was probably as a vegetable relish rather than as a beverage. To tea, also, the early Chinese attributed medicinal value, and to-day Oriental peoples impute to it at least health-giving virtues. In China and Japan, tea and its use interweaves with philosophy and mystic belief; tea ceremonies partake of the nature of religious rituals.

A Japanese writer[1] states that the evolution of tea "may be roughly divided into three main stages: the Boiled Tea, the Whipped Tea, and the Steeped Tea." In primitive days "It was not only administered as an internal dose, but often applied externally in form or paste to relieve rheumatic pains. The Taoists claimed it as an important ingredient of the elixir of immortality. The Buddhists used it extensively to prevent drowsiness during their long hours of meditation," a practice reminiscent of the early Arabian use of coffee.

As to primitive use of tea: "The leaves were steamed, crushed in a mortar, made into a cake, and boiled together with rice, ginger, salt, orange peel, spices, milk, and sometimes with onions!"

Later, in the Tang Dynasty (618–907 A.D.) the poet and sage Luwuh (later worshipped as tutelary god of Chinese tea merchants) produced a three-volume *Holy Scripture of Tea,* in which he dealt at length with the proper methods of making the beverage. "There are three stages of boiling; the first boil is when the little bubbles like the eye of fishes swim on the surface; the second boil is when the bubbles are like crystal beads rolling in a fountain; the third boil is when the billows surge wildly in the kettle. The Cake-tea is roasted before the fire until it becomes soft like a baby's arm and is shredded into powder between pieces of fine paper. Salt is put in the first boil, the tea in the second. At the third boil, a dipperful of cold water is poured into the kettle to settle the tea and revive the 'youth of the water.' The beverage was poured into cups and drunk. O nectar! The filmy leaflet hung like scaly clouds in a serene sky or floated like water-lilies on emerald streams."

In the Sung Dynasty (960–1278) "the whipped tea came into fashion. . . . The leaves were ground to fine powder in a small stone mill, and the preparation was whipped in hot water by a delicate whisk made of split bamboo. . . . Salt was discarded forever."

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[1] Okakura-Kakuzo, *The Book of Tea,* pp. 26 ff. By permission of Duffield & Green, publishers, New York.

The modern custom of steeping was developed in the Ming Dynasty (1368–1644).

In Japan, the tea ceremonies link themselves with Taoism and its successor, Zennism.

While the world-crop of tea in pounds is less than that of coffee, undoubtedly greater volumes of tea infusion are drunk than of coffee-brew. A pound of tea furnishes about 250–300 cups; one of coffee, forty.

Outside the Orient, England and her possessions lead in tea consumption. In Great Britain, between eight and nine pounds are used per person per year. The United States is far below with 0.8 pound. Russia is a large consumer of tea; the United Kingdom, Russia, United States, Canada, and Australia together take about 80 per cent of world exports. Fig. 360 shows the sources of the principal tea imports of the United States. That shown for the United Kingdom originates mostly in India and Ceylon.

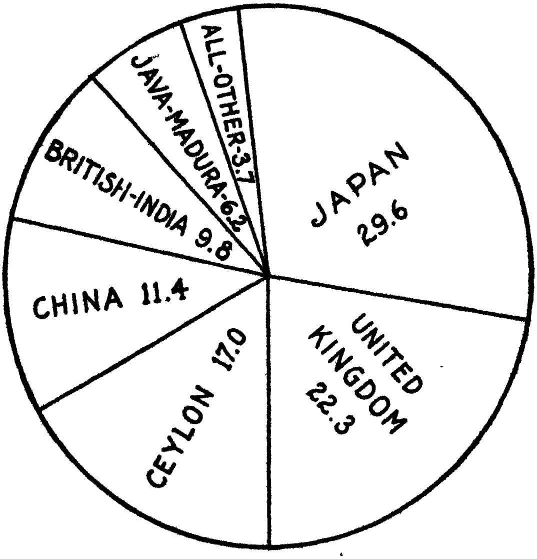


FIG. 360. — Sources of American Imports of Tea, for a Selected Year. The total is 89,161,000 pounds. (From Statistics by the United States Tariff Commission.)

Because of the formerly frequent practices of adulterating tea with tea waste and artificial coloring or "facing," imports into the United States are very strictly inspected and made to conform with official standards before their admission to our ports.

Cacao, Chocolate, and Cocoa

The cacao tree, *Theobroma Cacao,* belongs to the Sterculiaceæ; it is native to coastal Mexico, Central America, and northern South America. The word *cacao* seems to be a doubled derivative of the Indian *ca*—plant; and *cocoa* is a more easily pronounced corruption of cacao. *Kakahautl* or *chocolatl,* as it has been variously rendered, was greatly prized by the Aztecs, and its mention figures prominently in the early accounts of the Spanish conquest. Pizarro found it also in Peru. In Mexico the seeds were collected in lieu of taxes and were used in quantity as currency. The royal household is said to have consumed enormous quantities of chocolate. While emperors are notably profligate with both currency and food, even when uncombined, the Spanish chroniclers' report that Montezuma consumed an amount of cacao almost equal to the entire world output to-day is a little incredible.

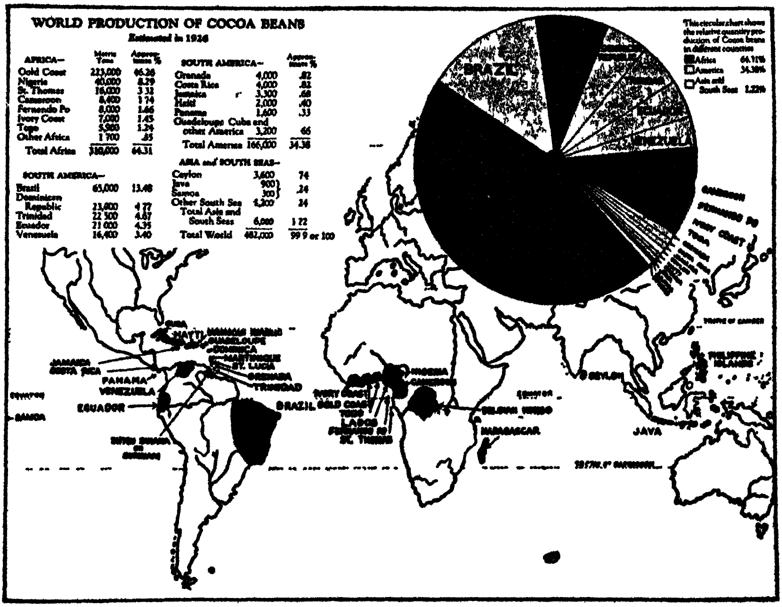
Chocolate presently appeared in Spain and is first reported in England about 1657. Thus at almost the same time, coffee, tea, and chocolate came into use in Great Britain.

To-day Mexico is of little significance in cacao production; the Philippines, to which the Spaniards early transplanted the tree, scarcely figure in world chocolate trade. On seacoasts and islands of northern South America and western Africa, in the doldrum region, or zone of calms, which extends about 13° on either side of the equator, is found the principal cultivation of cacao (Fig. 361). The hot, humid lowlands of Ecuador were for a time the chief center of production of high-grade cacao, and the crop is still the leading export of that country, where single plantations contain millions of trees. Larger quantities are grown in Brazil; considerable amounts in Venezuela. In the Caribbean islands, the Dominican Republic and the small British possessions of Trinidad and Tobago lead.

In Africa, the British colony of Gold Coast produces over half the world's total of 1,000,000,000 pounds; it might more appropriately be called the Cacao Coast. Nigeria ranks third—second to Brazil.

THE CACAO TREE

Theobroma Cacao becomes twenty to twenty-five feet high in cultivation, and forty feet or more when growing wild. The rather thin and lustrous evergreen leaves are elliptic-oblong and about a foot in length. Blossoms are rather small, with rose-colored calyx and yellowish corolla. They are produced in a rather odd fashion in fascicles from axillary buds on the main stem and branches of the tree (Fig. 362). The pods which follow are somewhat cucumber-shaped, elliptic-ovoid, four inches in diameter and six, nine, to even more than twelve inches in length, five-celled and ribbed, with warty protuberances, and grayish or yellow in color. From twenty to forty-five flattened seeds, the cacao "beans," each about an inch in length, are embedded in gelatinous pulp. Seed color varies in different varieties.



WORLD PRODUCTION OF COCOA BEANS
Estimated in 1926

AFRICA—	Metric Tons	Approximate %
Gold Coast	223,000	46.26
Nigeria	40,000	8.29
St. Thomas	16,000	3 32
Cameroon	8,400	1 74
Fernando Po	8,000	1.66
Ivory Coast	7,000	1.45
Togo	5,900	1.24
Other Africa	1 700	.35
Total Africa	310,000	64.31

SOUTH AMERICA—	Metric Tons	Approximate %
Brazil	65,000	13.48
Dominican Republic	23,000	4 77
Trinidad	22 500	4.67
Ecuador	21 000	4.35
Venezuela	16,400	3.40

SOUTH AMERICA—		Approximate %
Granada	4,000	.82
Costa Rica	4,000	.82
Jamaica	3,300	.68
Haiti	2,000	.40
Panama	1,600	.33
Guadeloupe Cuba and other America	3,200	.66
Total America	166,000	34.38
ASIA and SOUTH SEAS—		
Ceylon	3,600	.74
Java	900	.24
Samoa	300	
Other South Sea	1,200	.24
Total Asia and South Seas	6,000	1 22
Total World	482,000	99 9 or 100

This circular chart shows the relative quantity production of Cocoa beans in different countries

■	Africa	64.31%
▨	America	34.38%
☐	Asia and South Seas	1.22%

FIG. 361 — The Geographic Story of the World Production of Cocoa Beans, 1926. (Courtesy of D. Ghirardelli Co)

Cacao culture and harvest.—The cacao tree is very sensitive to frost, wind, and drought; it does best in rich soil, humid climate, and low altitude. Seeds or seedlings are planted in the field, and shade is usually given at least at first. Valuable trees are occasionally chosen to furnish grafting-wood. Bearing begins at three to five years; the maximum yield is reached at about twelve, after which production may continue for forty to fifty years.

There are usually two harvests a year. Pods are carefully cut off with a sharp knife or hook and opened with machetes or other heavy knives. The seeds, which vary from ivory white to delicate violet, are scooped out by hand and usually fermented before drying. For this process they are placed in large sweating-boxes three to seven feet in depth and covered with leaves or matting. Fermentation progresses about a week; during this time the beans are stirred and moved from box to box to equalize aeration and temperature. The slimy pulp which adhered to the fresh seeds liquefies and flows out through holes in the bottom of the boxes The beans become reddish and aromatic; when sufficiently fermented they are dried by sun or by artificial heat.

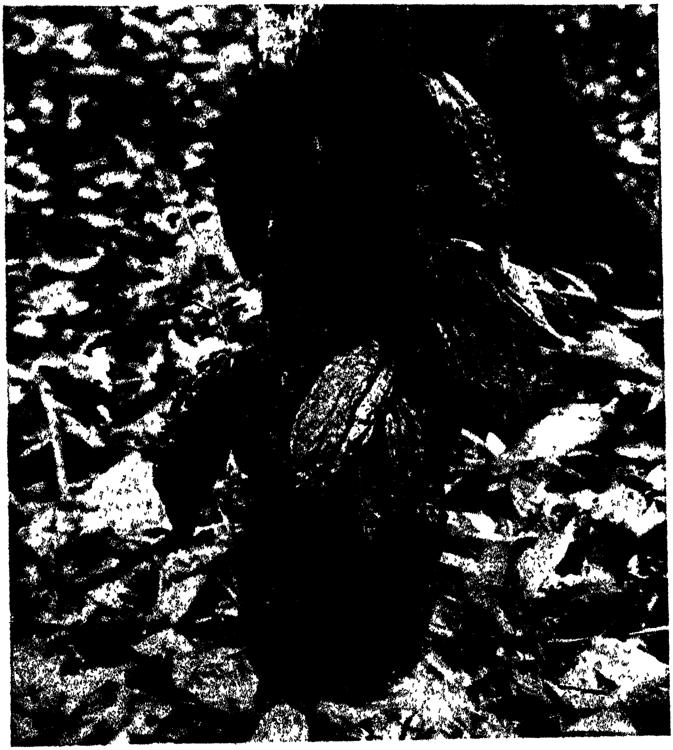


Fig. 362. — Trunk of Cacao Tree (*Theobroma Cacao*) Bearing Ripe Pods. (From Wilcox, *Tropical Agriculture*, D. Appleton Company.)

Some cacao is dried without fermentation.

THE CACAO BEAN AND ITS PRODUCTS

From viewpoints of significant constituents and uses, the cacao bean is a much more complex thing than the coffee seed or tea leaf. Aside from the brownish red seed-coat or cocoa shell, which is ordinarily removed before grinding, the large dicotyledonous kernel contains 30–50 per cent of a fixed oil, solid at ordinary temperatures, called cacao or cocoa butter; 15 per cent of starch; 15 per cent of proteins; 1 to 3 per cent of theobromine; 0.07 to 0.36 per cent of caffeine. The coloring matter formed in fermentation is called cacao red.

FIG. 363. — Roasting Cocoa Beans. (Courtesy of D. Ghirardelli Co.)

The principal products made from the bean are CACAO BUTTER, CHOCOLATE, and COCOA. These are prepared in American and European factories. The process is basically as follows: The beans, still in their seed-coats, are carefully cleaned by machinery and then roasted one and one-half to two hours in huge revolving cylinders (Fig. 363). They are cracked by corrugated rolls and the broken cotyledons—cocoa nibs—are separated from the shells. In times past the shells were sometimes ground and mixed with cheap grades of cocoa or brewed alone into drink of decidedly "washy" character. They are now mainly used for fuel in the roasting furnaces.

Nibs are ground in stone-mills. The first mill is heated; this liquefies the oil of the seed; the product of grinding is an oily paste, the chocolate liquor. Cooled and hardened, it becomes chocolate. For manufacture of cocoa, hydraulic presses express part of the oil through camel's hair filters; the residue, when powdered, is breakfast cocoa. Chocolate of varying fat content may be prepared by re-mixing cocoa with different proportions of chocolate liquor. Vanilla and sugar is added if sweet chocolate is desired. Cocoa should still contain 22 per cent of fat.

Cacao butter does not become rancid; it is used in chocolate manufacture, in chocolate coatings for candies, in pharmaceutical preparations, and for massaging. The uses of chocolate and cocoa are too well known to require elaboration, although the Aztec Montezuma—used to a mixture of ground cacao beans and water, taken unsweetened and cold, flavored with vanilla or perhaps green peppers—would perhaps not recognize either modern preparation.

The sweet tooth of America demands nearly three pounds of chocolate and cocoa per capita per year. This figure is second in the world, slightly in excess of that of Great Britain, and far behind the achievement of Holland—10.5 pounds.

The use of cocoa waste in theobromine manufacture has been mentioned. Theophylline may be made from theobromine, and also caffeine.

Other Caffeine Beverages

Caffeine-bearing plants are somewhat widespread, both botanically and geographically, and theobromine occurs occasionally, usually in insignificant quantity, outside the genus *Theobroma*. Several beverages allied to coffee and tea are used among primitive peoples, but none has attained anything like the world-wide use of the three staple beverages.

COLA

The cola or cola nut consists of the dried cotyledons of *Cola nitida* or other species of *Cola*. These are West African trees belonging, like *Theobroma*, to the Sterculiaceæ. The cotyledons, plump and fleshy when fresh, become plano-convex, polygonal, and indurated on drying. Seeds of some species furnish more than two cotyledons; one, as many as six.

Cola was first known as the source of an African beverage. The trees are now cultivated in the West Indies, whence most American supplies are derived. The cotyledons contain 1.5 to 3.6 per cent of caffeine and 0.02 to 0.09 per cent theobromine. They are sometimes used medicinally for the caffeine effect. The name "cola" is used for popular soft drinks; the limited imports of the product indicate that the considerable caffeine content of these beverages is derived from other sources.

GUARANA

Guarana, sometimes misleadingly known as Brazilian Cocoa, is a dried paste made of the crushed seeds of *Paullinia Cupana* of the Sapindaceæ. The plant is a climbing shrub of Brazil, where it is also cultivated. Guarana is formed into reddish or blackish-brown cylindrical sticks one and one-half to two inches in diameter and six to twelve inches in length, suggesting petrified sausages, or into flattened cakes. The caffeine content of guarana is highest of commercial plant products—2.5 to 5 per cent; it also contains much tannin. It is occasionally used in American medicine. Large quantities are employed as a beverage in Brazil. The flavor is astringent and bitter-sweet.

YERBA MATÉ

Yerba maté, or Paraguay tea, consists of the leaves of *Ilex paraguayensis*, of the Aquifoliaceæ. The tree is a small evergreen somewhat resembling the orange tree in habit. The leaves are lanceolate and shallowly serrate, six to eight inches in length, with some resemblance to large tea leaves. *Ilex paraguayensis* occurs in forests in Paraguay and southern Brazil, where it has been used from time immemorial by the Indian natives. It was first cultivated there by Jesuit missionaries; collections to-day are from both wild and cultivated plants.

Leafy branches of the tree (Fig. 364) are cut and partly dried over flames; the leaves are then beaten off and fully dried on frameworks over open fires. They are coarsely powdered in pits dug in compacted earth. For marketing, quantities of about 200 pounds are sewed up in rawhides; the latter, contracting as they dry, compress the leaves into a compact package.

The term *yerba* is Spanish for herb; *maté* denotes a gourd. The beverage is usually made by placing the leaf in a hollowed gourd and pouring sweetened boiling water over it. It is taken through a *bombilla* (Fig. 365)—a hollow-handled device midway between a spoon and the American tube for iced tea. Natives of central South America drink quantities of yerba maté with every meal, consuming about an ounce of dried leaves per day. A more detailed estimate of consumption, made several years ago but stated in the publication cited to be probably approximately correct in 1928, follows:[2]

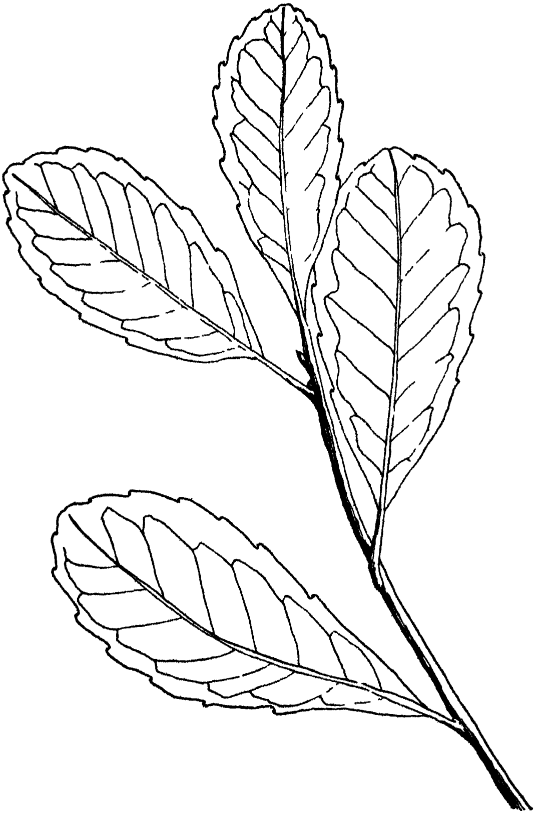


FIG. 364. — Branch and Leaves of Yerba Maté (*Ilex paraguayensis*). (E. Coffman.)

"A reasonable and impartial estimate places the number of drinkers of Paraguay tea at about 10,000,000 persons in South America;

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[2] Albert Hale, formerly of the American Embassy at Buenos Aires, quoted in "In Yerba Maté Forests of South America," Pan American Union Commodities of Commerce Series No. 4, 1928.

and it is stated that the supply frequently falls short of the demand. The yearly consumption per capita of this *yerba* in Chile is given at 112 pounds; in Bolivia, 4½ pounds; in Argentina, 20 pounds; in Uruguay, 22 pounds; in Paraguay, 34 pounds; and even in the great Brazilian State of Parana, from which come great quantities of Maté, although it is near the coffee-growing center of the world, the annual per capita consumption is 44 pounds. This is a demonstration of the influence the habit makes upon the European immigrant even from the northern portion of that continent, for Paraguay and Brazil have a large proportion of Germans and Poles among their colonists."

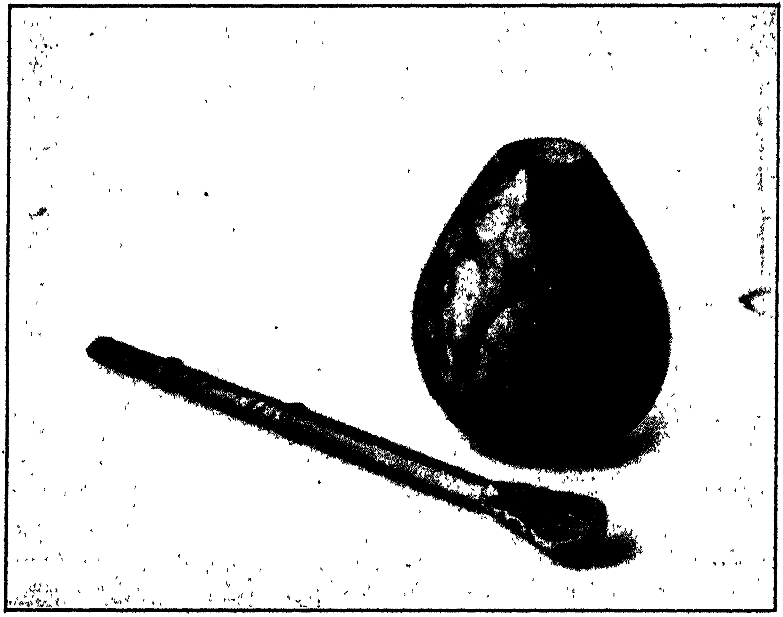

FIG. 365. — The Cuya and Bombilla. Yerba maté leaves are placed in the *cuya* or gourd and hot water sweetened with sugar poured over them. Some persons add the juice of a lemon. The drink is usually taken through the *bombilla*, the lower part of which acts as a strainer. (Courtesy of the Pan American Union.)

If this estimate for Chile is even approximately correct, it should be a world's record for caffeine-beverage consumption.

The infusion of yerba maté is bitter; despite the comment quoted above, it does not gain popularity in Europe or North America. Imports to this country are commercially negligible. Recent efforts have been made to develop from maté beverages better suited to the American taste.

Maté contains about 0.9 per cent caffeine.

CHAPTER XVI

MEDICINAL PLANTS

Primitive Medicine

Aromatic, pungent, and more or less violently poisonous plants are found everywhere on the habitable globe. Animals generally, but not invariably, discriminate between nutritious and deadly plant products; and primitive man, from necessity, learned to know the healthful from the lethal, and in the learning doubtless had plenty of opportunity to observe the physiological effects of poisonous plants.

Savage peoples generally impute disease, particularly mental disease, to the intrusion into the ailing body of malevolent spirits or demons, and this theory of demoniacal possession has survived more or less completely in peoples of considerable culture. Logically enough, barbaric races have striven to combat the supposed demons of disease with measures calculated to make the chosen human tenement unpleasant or uninhabitable to the intruding spirit. The use of poisonous, nauseous, and otherwise disagreeable products of the plant kingdom was readily suggested, no doubt, by accidental or experimental experience with physiologically powerful fruits, leaves, barks, or the like. Such practices are carried on to-day by medicine men of savage tribes, and doubtless the usage dates to the beginning of the race. Perhaps one of the earliest differentiations between man and his more brutish ancestors may have been the efforts of the former to combat disease. When the theory of demon possession was more or less outgrown, remembered observations of results—beneficial or otherwise—of the medicine-man's potions remained to guide the early physicians who endeavored to treat the sick. Drug products, like spices and aromatics, were staples of primitive trade. Even to-day, a gullible world is all too ready to believe in advertised virtues of "Indian Remedies" and medicines imputed to the "children of nature" of other climes. The majority of primitively used medicinals are quite valueless, although it is true that some of the most important drugs which maintain their value under the scientific scrutiny of modern medicine were first employed by savage races.

The ancient Greeks, the Romans, and the Arabians were students of disease and its treatment. Plant products, some active and some useless, were employed in the materia medica of each nation. With little understanding of the functioning of the human body and of the nature of disease, their contributions to medical science could scarcely be of lasting value. The Europeans of the Dark Ages did little but rehearse the teachings of the classic writers of Greece and Rome.

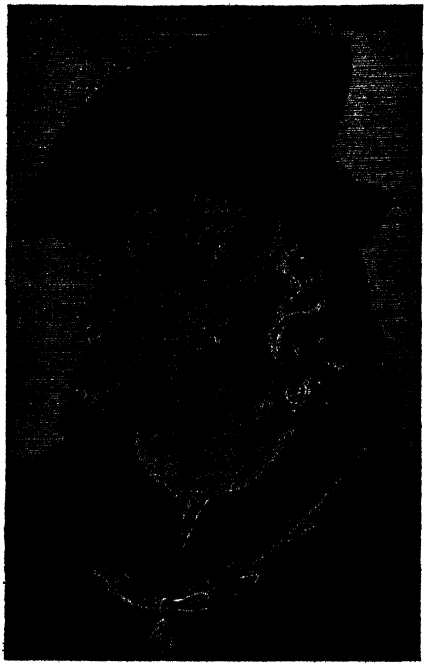

FIG. 366. — Paracelsus, an Eccentric Genius of the Middle Ages. (From Garrison, *History of Medicine*, W. B. Saunders Co.)

The Doctrine of Signatures

In the Middle Ages, in part as the result of the work of the erratic genius Paracelsus (1490?–1541) (Fig. 366) arose a peculiar belief known as the DOCTRINE OF SIGNATURES. Briefly stated, this doctrine implied that all things were useful to the human race (in a more modern phrase "good for something") and that the indication of value might be found in a mystic sign or signature borne by the object. The resemblance of a structure to a portion of the human body, in particular, was seen as a signature indicating value in treatment of ailments of the organ in question. The varied forms of plants and plant parts, obviously, offered unlimited field for the credulous eye; and the search for signatures became the principal end of life to many medieval physician-botanists. Plants, for example, with heart-shaped markings or with heart-shaped leaves were eagerly sought for cardiac (or supposedly cardiac) disorders, and several quite valueless and unrelated plants to-day bear "hearts-ease" as a common name. The walnut, whose "meat" somewhat resembles the hemispheres of the brain (Fig. 367), was used for various disorders of the cranium, mental and otherwise.

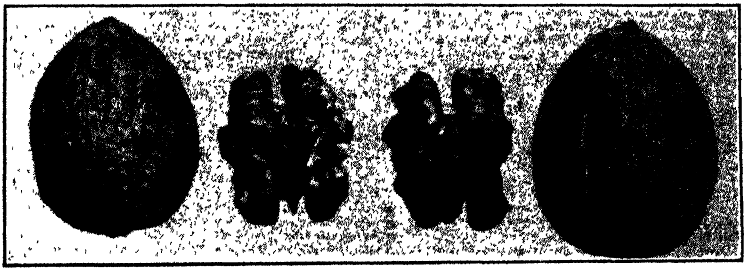

Fig. 367. — The Doctrine of Signatures; the Brainlike Hemispheres of the Walnut. (Photo from California Agricultural Experiment Station.)

The Doctrine of Signatures, little more scientific in fact than the ancient theory of demoniacal possession, could not long withstand the progress of medical science; but it did incite an eager experimental study of the plant kingdom, thereby adding much to knowledge of plants, if little to logical treatment of disease. A class of practitioners known as HERBALISTS flourished in England and on the Continent. Their bulky tomes, laboriously filled with plant lore of mingled fact and fable, illustrated with quaint wood-cuts, are collectors' hobbies to-day. In the early settlement of the United States pioneers and physicians, deprived of European remedies, experimented eagerly with a wealth of new plant species. In one way or another, through accident or experiment, there is scarcely a genus of higher plants known to the present-day world which has not at some time been tried out in medicine. The armamentarium of the modern physician, it must be admitted, carries relatively few products of the plant kingdom, but these few are the result of a vast amount of experimental winnowing.

Modern Medicine and Its Viewpoint

Because of the complexities of the human organism, medicine to-day cannot be termed an exact science, but certainly it strives, with increasing success, to approach that ideal. Diseases, it is now understood, may be divided into two more or less distinct classes: those which result from imperfection of the human machine and those caused by some invading agent—bacterial, fungus, or protozoan.

It is now rightly recognized that the province of the physician includes not only the sick but the well. Prevention of disease is vastly better for the individual and the race than its cure. Modern medicine finds itself more and more concerned with personal and social hygiene, prophylaxis (the prevention of infectious disease), nutrition, exercise, and the conditions of living, and correspondingly less with the actual treatment of disease. Even in the latter field it is thoroughly recognized that the human organism is its own best curative agent; that drugs, surgery, and other drastic methods of treatment are only aids to the recuperative powers of nature. That drugs, for example, are decreasing in medicinal importance does not, however, indicate their eventual elimination. Despite the progress of preventive medicine, disease still occurs; mortality may be postponed but not prevented, and, to some extent at least, physiologically active substances will always be employed in the never-ending warfare against illness and death.

Medicines, Foods, and Poisons

These groupings are less clearly defined than they seem. FOODS have been previously (Chapter IX) defined as substances which afford material or energy for organic growth or function. MEDICINES, strictly speaking, influence function without offering material to sustain it. POISONS are generally defined as materials which by contact with the organism interfere with its well-being and functions so as to cause disorder or death. Whether a substance is to be classed as a medicine or a poison depends less on its nature than on the circumstances of its action and the amount used. Almost anything which has enough physiological activity to serve as a medicine may also be a poison if injudiciously used. Many, but by no means all, poisons are valuable medicines if properly utilized. In the organic world, moreover, substances are far from simple in character and composition. A root, for example, may be rich in starches and other foodstuffs, yet be classed as a poison or used as a medicine because of a quantitatively insignificant amount of some constituent of extreme physiological activity. Cassava root is violently poisonous; a simple treatment involving the use of heat drives off the toxic constituent, and the residue, as tapioca and related products, is highly important in the world's dietary.

Medicinal Action

Many things whose mode of action is as yet quite uncertain are used with apparent good effect in the treatment of disease. Some theories of particular medicinal actions are quite too complex to discuss in the present connection. In many cases, however, the effect of an active substance is to stimulate or to depress some organic action or bodily function. Such a material is usually unnecessary to the normal functioning of a healthy organ or organism, and if used may by overstimulation or overdepression act as a poison. If by disease, however, a given function is overstimulated or unnaturally depressed, the administration of a sedative or stimulant, as the case may be, may result in the restoration of more normal function. In some cases also, as in the relief of pain, the use of a properly selected medicinal may, by diminishing the sensibility to pain, afford the body rest and aid in recuperation. The use of many of the best-known drugs is based on these general principles.

Divisions of Modern Medical Practice

Early physicians not only administered, but collected and prepared their medicaments. Only exceptionally is this practice followed to-day. In general, the physician merely writes a formula, the PRESCRIPTION; the ingredients may be gathered from several continents, prepared by a pharmacist, and administered by a trained nurse. It is of course the province of the physician to know the action of drugs singly and in combination. It is that of the pharmacist to insure the identity and proper preparation of the medicaments. In the manufacturing of medicines, as in many other industries, large-scale processing tends to replace small and local compounding. Many prescriptive mixtures are of routine use in large quantities, and plentiful supplies of these as well as larger amounts of package and "patent medicines," much used without the supervision of a physician, are prepared by great drug manufacturing houses. In any event, an accurate knowledge of materials is essential to effective medication. Many plant drugs, in particular, may be adulterated, imitated, or mistaken by unscrupulous or ignorant collectors or handlers, with disastrous or even fatal consequences. Therefore, in the United States and other civilized countries, legal specifications exist, which govern the identity and quality of medicinal products. These are enforced by inspection services employed by and empowered under national and local laws. Drug inspectors must be versed in both the botanical and chemical natures of medicinal products. Like other procedures of law and legal system, drug inspection is not 100 per cent perfect, but the purity and identity of medicines used to-day is far more carefully guarded than ever before.

1. VEGETABLE DRUGS

The Nature of Vegetable Drugs

The potent principles for which plants are valued in medicine belong to various chemical categories. The most striking group is that of the alkaloids—nitrogenous organic bases occurring almost solely in the plant kingdom and principally among the dicotyledons. Most of these are powerful poisons, and many are valued medicinally. Another interesting group is the glucosides—complex organic compounds known by their property of decomposition by specific enzymes, the resultant products being a sugar, typically glucose, and one or more other substances. Many glucosides are quite inert physiologically; the action of others is due to the compounds linked with the sugar. The enzyme which breaks down a given glucoside is usually to be found in the same plant but probably not in the same cell. Among other plant compounds of medicinal value are various volatile oils, resins, gums, tannins, etc.

The active principles of plant drugs are commonly most concentrated in storage regions. Some of them also occur in quantity in leaves. Roots, seeds, and barks are much represented in the materia medica; flowers are less commonly employed, while woods and woody portions of herbaceous stems are usually relatively inert.

The rôles of physiologically active substances in plants are in most cases debatable. Alkaloids, being nitrogenous, may perhaps result from protein decomposition. By their poisonous nature they are usually repellent to animals; on this account they have been assigned "protective value." In many cases, however, the actual amount present seems too small to have any evident significance in this respect. It has been inferred that the presence in seeds of such glucosides as amygdalin in the bitter almond, may be of nutritional value, inasmuch as during germination the amygdalin breaks down and the sugar is presumably utilized by the seedling. The other compounds formed, benzaldehyde and hydrocyanic acid, are poisonous, odorous, and perhaps repellent. Volatile oils of flowers are apparently attractive to insects which effect pollination.

Preparation of Drugs for Market

With a few exceptions, such as opium and cinchona, plant medicinals are not products of cultivation. As compared with such agricultural staples as cotton or the cereals, or even with relatively minor truck crops, the market for most individual drugs is relatively small, abundantly supplied by wild plants, and easily and disastrously "flooded." The collection of the wild and free products of field and forest is usually so little remunerative as to attract only the cheapest classes of labor—old men, women, and children, in regions of primitive culture. These facts render efficient inspection of products the more essential. The plant parts are merely freed to greater or less extent from adherent earth or trash, and dried, usually in the sun but sometimes by special methods. In the dried state, the products are commercially known as CRUDE DRUGS.

In the making of prepared medicines, of course, further processes are employed. These vary from simple grinding to the complex chemical operations essential to the freeing and purification of alkaloids.

Regions of Collection and Traffic in Crude Drugs

Drug plants as a class are of world-wide distribution, but their commercial collection is chiefly localized in regions of little culture, little diversification of industry, and considerable uncultivated land. In the United States, drug gathering centers in the mountain regions of the Southern Appalachians in Virginia, North Carolina, Kentucky, and Tennessee. The native flora here is extremely rich both in medicinal and non-medicinal species (Figs, 368, 369); and an enormous variety of products is collected, much of it entering commerce by barter at country stores. Most of the Southern Appalachian products are of little therapeutic importance, being used chiefly in proprietary medicines.

Drug collection is also carried on in forested and primitive regions in various European countries, particularly in Germany, Italy, and Czecho-Slovakia. Many other products are obtained from scattered regions all over the earth.

Before the World War, commerce in drug products centered chiefly in Germany and in the port of Hamburg. London, Trieste, and Marseilles were also other important world centers. New York, through which port passes nearly all American commerce in crude drugs, increased its eminence during the war, and since has been the chief international center of trade in drugs.

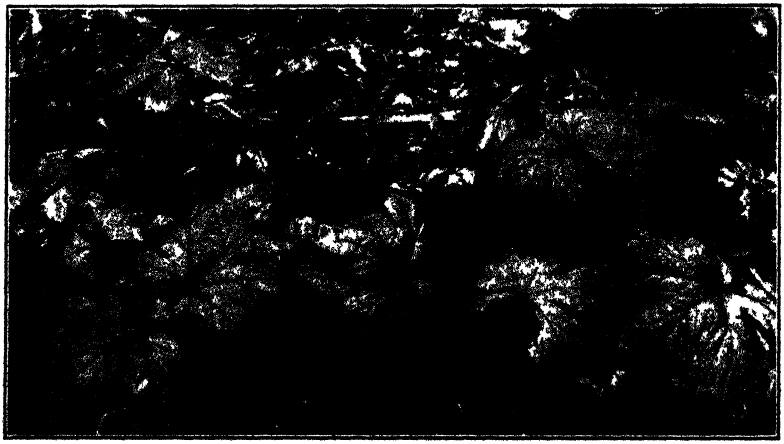

FIG. 368. — Goldenseal (*Hydrastis canadensis*). A woodland plant of the Midwest and Southern Appalachians, now almost exterminated because of the demand for its underground stems for medicinal use. (Courtesy of Bureau of Plant Industry.)

2. IMPORTANT DRUGS

Opium and Its Products

Opium is the air-dried juice of the capsules of the Opium Poppy (*Papaver somniferum* and its variety *album*) (Fig. 370). It owes its uses chiefly to the alkaloid morphine, of which medicinal grades contain 9.5 per cent or more.

The plant (Fig. 400) is a large one with handsome flowers, closely related to the common garden poppies. It is cultivated for opium production chiefly in two regions. Medicinal opium comes largely from Asiatic Turkey; smaller quantities are furnished by Persia, Greece, and Bulgaria. Opium of a lower alkaloidal content is produced in large amounts in China and India. It is mainly used for non-medicinal purposes—in China for smoking and in India for "eating."

The opium poppy plant contains considerable quantities of milky juice, or latex. The capsules, resembling those of common poppies and from one to two inches in diameter, are incised when full-sized but unripe. The latex exudes and hardens to a

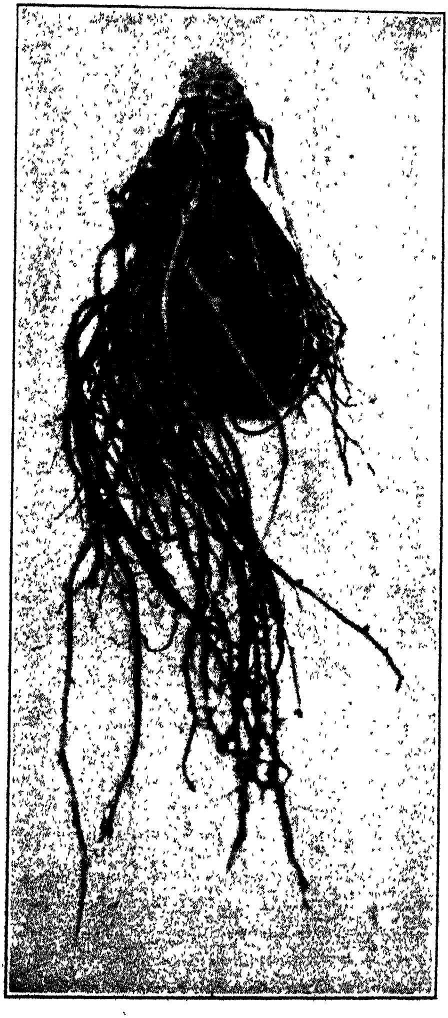

FIG. 369. — The Medicinal Parts, Rhizome and Roots, of Goldenseal. (Courtesy of Bureau of Plant Industry.)

plastic consistency on the surface. It is later scraped off, dried somewhat further, and sent into commerce (Fig. 371). The production of opium on a commercial scale demands rich agricultural soil and cheap and seasonally abundant semi-skilled labor. Even before the existence of any legal obstacles to its general production, these factors had virtually limited it to the regions above mentioned.

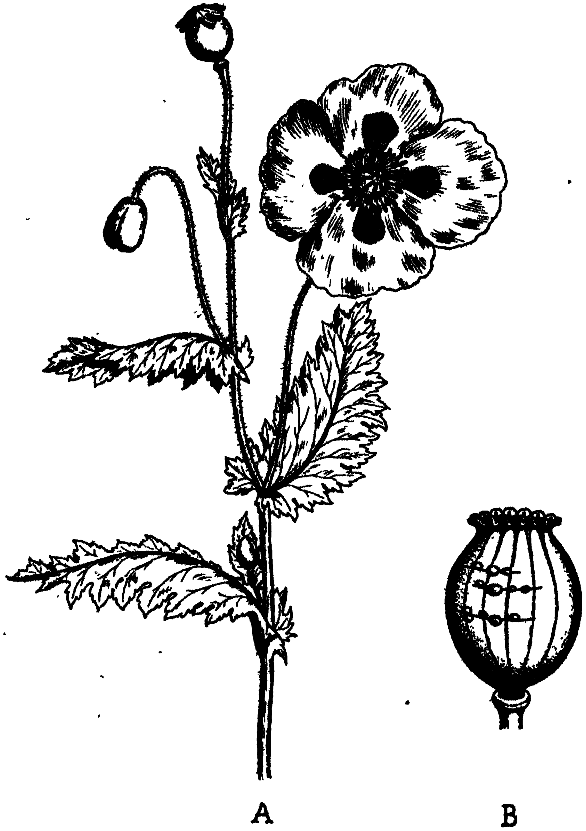

FIG. 370. — Opium Poppy (*Papaver somniferum*). *A*, flowering top; *B*, incised capsule with latex exuding. (*A*, after Engleder; *B* after Thoms, E. L. Spuller.)

Opium and its products, among which morphine is chief, are indispensable in relieving certain forms of pain; but the effects of their habitual misuse are inevitable physical, mental, and moral degradation. The morphine habit is all but impossible to break. For these reasons, the handling of opium and its products in the United States and other intelligently governed countries is hedged with drastic and rigidly enforced restrictions. Attempts have also been made to limit international traffic through agreements between the various nations involved. These have been to some extent successful, though considerably hampered by

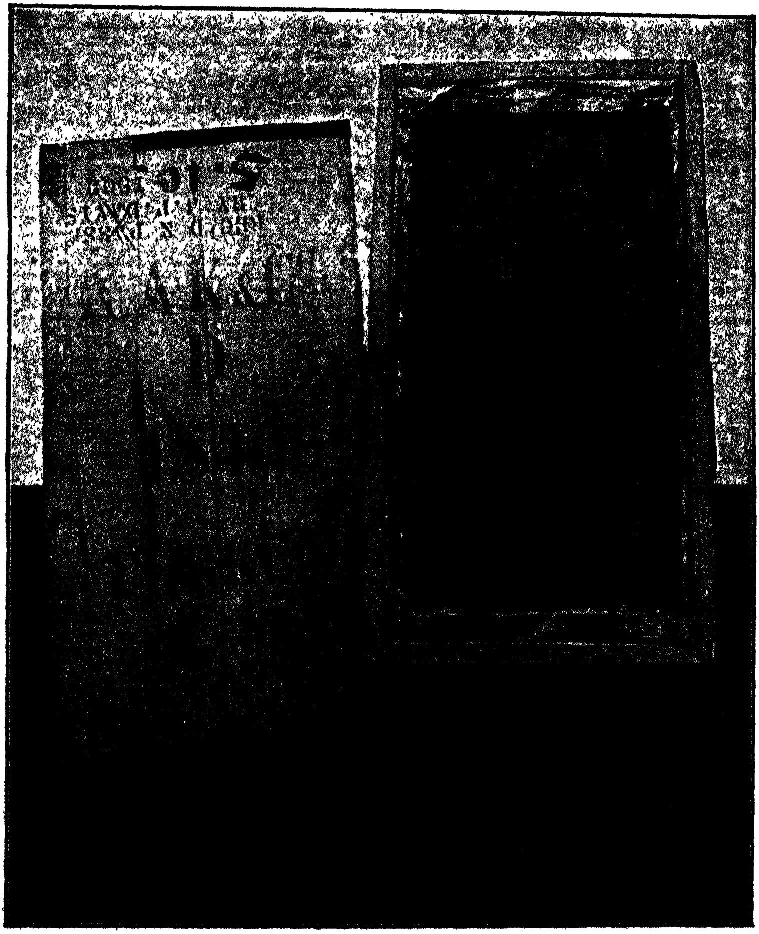

FIG. 371. — Original Packages of Opium Imported from Turkey. (Photo by Parke, Davis & Co. in *Scientific and Applied Pharmacognosy*, by the late Henry Kraemer, *et al.*, published by John Wiley & Sons, Inc.)

recalcitrance on the part of producing nations, in all of which large governmental revenues have been derived, directly and indirectly, from opium. The vast use of opium in China and its relation to production in India has been a prolific source of international dispute and ill-feeling. At the present time there is no legitimate opium trade between India and China, but tremendous amounts of opium are being raised and consumed in China under the disturbed governmental conditions in that land. Chinese opium production is estimated at eight times the amount produced and consumed in the rest of the world.

Regulation of international traffic in opium and other narcotics has been attempted by the League of Nations. In 1931, under the auspices of the League, an international convention was signed which places narcotics in the Occident under much the same system of regulation as that practised in America. This agreement, unfortunately, has little practical effect in the Far East. Japan, while stringently regulating drug traffic within her own borders, has come under open condemnation for fostering it in China and Manchukuo. Through a single Manchurian port Japan is alleged to have marketed as much as seventeen tons of morphine in one year.

The concentrated and powerful nature of morphine and its products—an ounce of morphine is equivalent to about 3,500 medicinal doses—renders it extremely easy to smuggle, and the high price which it commands in illicit trade makes the practice extremely difficult to combat. The suppression of the illegitimate use of opium products and allied narcotics is one of the gravest problems of public health to-day.

Coca Leaves and Cocaine

These are the product of certain tropical shrubs of the genus *Erythroxylon* (Figs. 372 and 373), which have been cultivated since prehistoric times in Peru and Bolivia, and which are now cultivated also in Java. Save for a confusing similarity in name these plants are not related to and have nothing in common with the cacao tree (*Theobroma Cacao*), the source of cocoa and chocolate. Coca leaves have been used as a masticatory by South American Indians since time immemorial. They contain about one per cent of the alkaloid, cocaine, an important local anæsthetic, the continual use of which gives rise to a habituation as disastrous as that of the opium products. The plant is non-hardy; its commercial production is closely limited by its climatic and soil requirements. Traffic in coca leaves and their products are subject to the same restrictions as those which govern opium. Considerable quantities of cocaine are manufactured in the United States, and the leaf-residue from which the alkaloid has been removed has been, according to reports from Governmental sources, extensively used in the compounding of soft drinks.

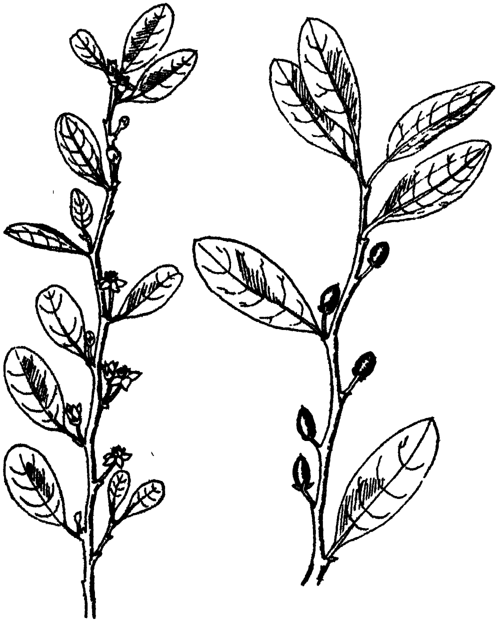

FIG. 372. — Two Varieties of Coca (*Erythroxylon Coca*). (E. Coffman.)

Cinchona and Quinine

Cinchona bark is the product of various species and hybrids of the genus *Cinchona,* non-hardy evergreen trees native to the forests of Peru and adjacent South America. Cinchona owes its use to several alkaloids, of which quinine is of chief importance as the most valuable drug known against the protozoan parasite which causes malaria.

Cinchona trees once formed an important portion of the Andean forests, but extensive collection of the bark with no intelligent effort at replacement of the trees has virtually exterminated the valuable species. Scarcity and high price of cinchona resulted in many attempts to cultivate the trees in other tropical regions, but continued success has been attained only in British India and the Dutch East Indies, where culture centers in Java. In both these regions culture was established and has been fostered by government aid. Without this it could scarcely have been carried through the early and experimental stages or have been maintained during subsequent years of overproduction and low prices, which eliminated a flourishing "infant industry" of cinchona in Ceylon. Java now dominates the world market in

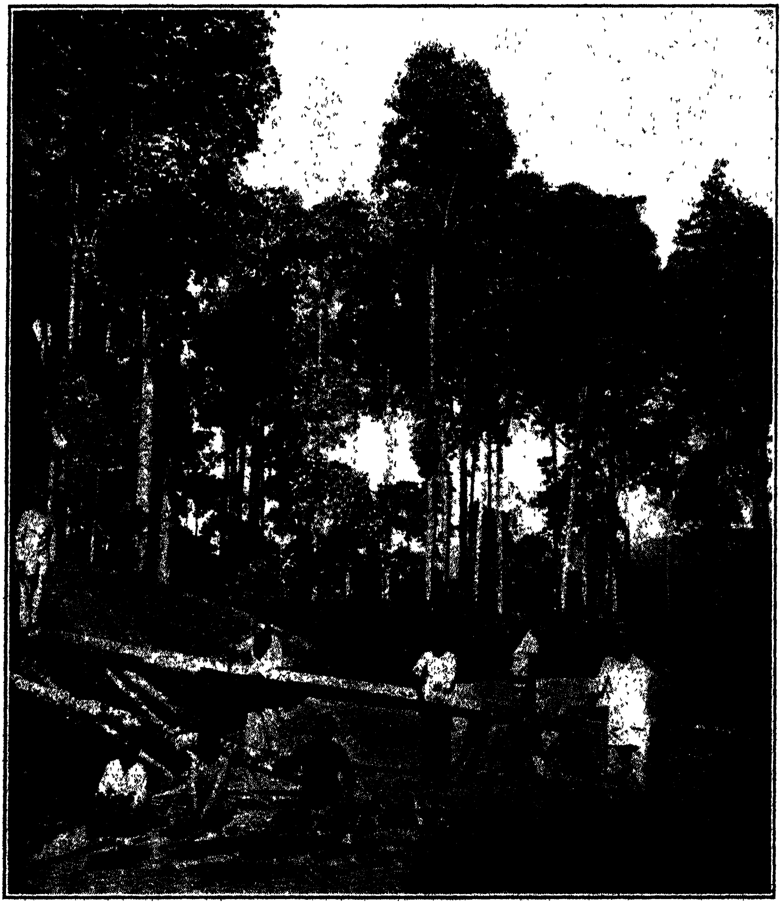

FIG. 373. — Peeling Cinchona Bark in Java. Cinchona trees are in the background. (Copyright, Dr. M. Kerbosch; used by permission.)

cinchona, and the virtual monopoly there has been so managed as to restrict output within limits profitable to planters without inordinate increase in the price of quinine. Not only is production closely regulated, but supplies are allotted and distributed to alkaloid manufacturers in the different countries under restrictions which virtually centralize cinchona-quinine control in Dutch hands. The output of British India is wholly consumed in India, and thus does not directly affect the world market. In recent years renewed interest in cinchona has been shown in other British tropical possessions, particularly in the former German colonies in Africa; British capital has also established itself to some extent in the industry in the Dutch East Indies, but no immediate weakening of the Dutch monopoly is to be looked for. Cinchona has been produced on an experimental scale in the Philippines.

Under cultivation, the cinchonas require rich soil and rather definite climatic and moisture conditions, which seem to be fulfilled very exactly on the terraced hillsides of Java. The industry here is also favored by an abundant supply of cheap but sufficiently skilled labor. The trees are cut and peeled at the age of about seven years (Fig. 373). The dried bark yields 5-9 per cent of alkaloids, principally quinine. While a few decades ago the bark was rather largely used for various medicinal purposes, at the present time practically the whole supply goes into alkaloid manufacture.

Cascara Sagrada

The bark of the Cascara Tree (*Rhamnus Purshiana*) (Fig. 374), is without doubt from a therapeutic standpoint the most important drug produced in North America, being in large demand for laxative purposes both in the United States and abroad. The tree is a rather small one, and occurs quite out of the ordinary regions of North American drug collection, being a native of the mountains of the Pacific northwestern States and adjacent Canada. It is peeled in the spring by lumbermen, ranchers, and Indians, and must be dried a year or more, or be specially processed, before being fit for medicinal use. Extensive collection has considerably depleted the wild supply. The tree reproduces well under natural conditions from seed, and occurs throughout a wide range of country of little value save for forest purposes. It is not improbable, however, that eventually supplies must depend on cultivation.

Ginseng

This mildly aromatic root is the product of two species of *Panax*. *P. Ginseng* of Manchuria and Korea, the original drug, is highly valued in China, and *P. quinquefolium*, an American plant which closely resembles the Asiatic, is exported for the Chinese trade in quantities which render it from a commercial standpoint the most valuable drug export of the American con-

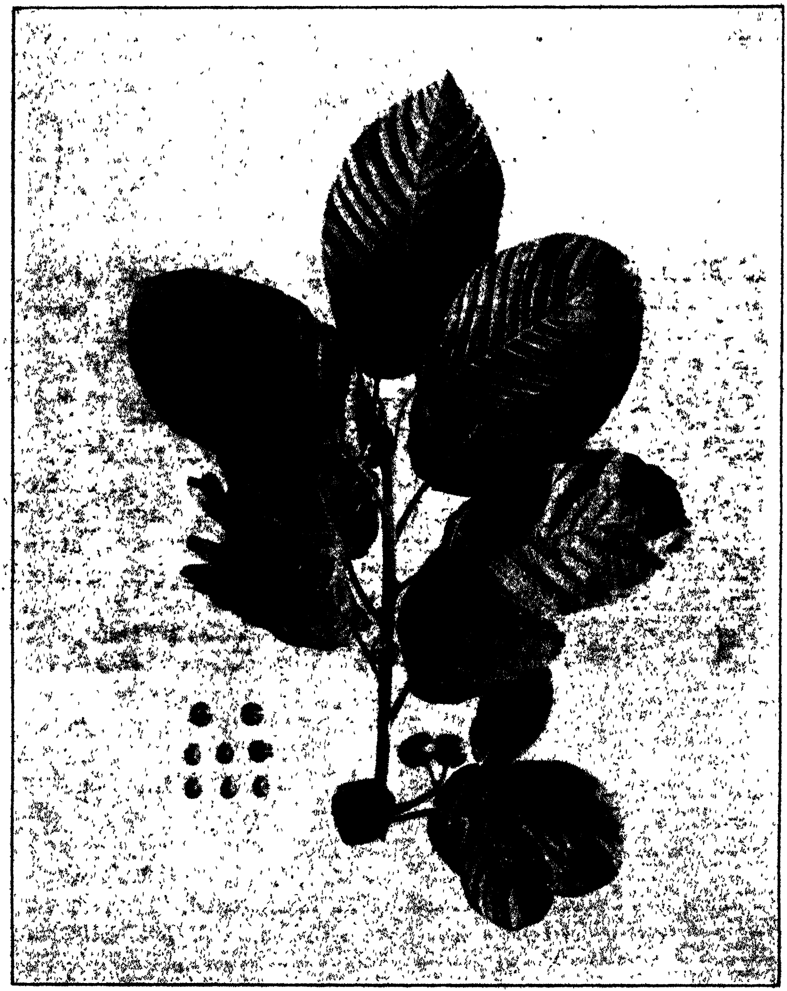

FIG. 374. — Leaves and Fruit of Cascara Sagrada (*Rhamnus Purshiana*). (Courtesy of Bureau of Plant Industry.)

tinents. The Chinese attribute to the drug various properties which Occidental research fails to substantiate. Ginseng is valued by Chinese buyers quite arbitrarily in accordance with the form of individual roots and the perfection of curing. Specimens most prized are those which bear a slight resemblance to the human form; especially good roots bring more than their weight in gold.

Extensive collection has almost exterminated American ginseng from its former considerable range in rich woodland from southern Minnesota and southern Canada eastward and southward to New England, the mountains of Georgia, and Missouri. Nearly all the ginseng now exported is cultivated in the natural shade of the woods (Fig. 375) or under artificial shade. The supposed great profits in ginseng culture have at various times been much advertised and have aroused great interest. Difficulties, however, are considerable; the plant requires a crop-period of several years, rich soil, and proper shade. Losses from disease are often heavy, and the crop is a constant temptation to thieves. The Chinese, furthermore, discriminate against cultivated ginseng, and are adepts at identifying it. Any successful attempt to produce it on a large scale would probably break the market disastrously. Such success as has thus far been attained has been only on a small-plot scale and by those who, at considerable expense in time and money, have become thoroughly familiar with the plant's peculiarities.

FIG. 375. — Ginseng (*Panax quinquefolium*) Cultivated in the Natural Shade of the Forest. (Courtesy of Bureau of Plant Industry.)

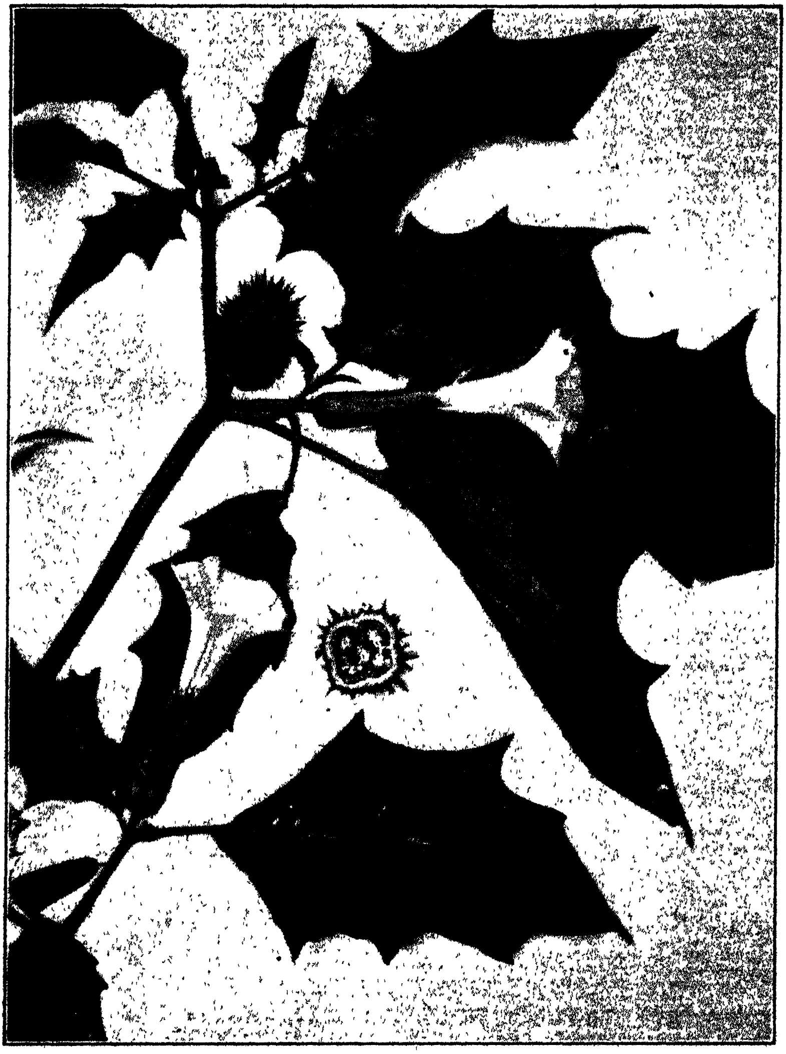

FIG. 376. — The "Jimson Weed" (*Datura Stramonium*). This is an American poisonous plant of considerable medicinal use, which has been occasionally cultivated. (Courtesy of Bureau of Plant Industry.)

Drug Plant Cultivation in the United States

Under ordinary conditions this industry is negligible. It has been carried on in a more or less experimental way for many years by the United States Department of Agriculture, and by various colleges of pharmacy, experiment stations, drug-manufacturing houses, etc. Cultivation and selection of highly valuable strains often results in a product of considerably better quality than is ordinarily obtained in the market, and in some cases quality has been further enhanced by improved methods of curing. The small demand for individual products, however, easily leads to oversupply and disastrous price-break. The necessities of valuable agricultural land, much hand labor—which in the United States is extremely expensive—and losses from insects and disease, usually increase costs to a point far above those of ordinary imported drugs. Cultivated drugs, then, must be sold at a "fancy" price on a strictly quality basis and to an extremely limited market.

During the World War supplies of several important drugs, originating in Europe, became extremely scarce or unobtainable. Among these were DIGITALIS—the leaves of the common garden Foxglove (*Digitalis purpurea*), an indispensable remedy for certain diseases of the heart, which was in great demand for use in army hospitals. Among others were several important drugs, from the Solanaceæ—BELLADONNA, HENBANE, and STRAMONIUM (Fig. 376) all alkaloidal in character and used for a variety of purposes. All had previously been cultivated in the United States in an experimental way, and under spur of war demands considerable amounts were produced in the last year of the war and for about a year afterward. Costs of production of these products are said to have averaged fifty cents per pound, whereas European drugs can under ordinary conditions be laid down in New York at from eight to fifteen cents. Resumption of European supplies brought sharp and disastrous price-break at a time when the domestic supply was already more than sufficient, and the "infant industry" of the production of these drugs was virtually wiped out of existence. There seems little prospect of its resumption.

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